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(71) Applicant (*for all designated States except US*): GENESENSE TECHNOLOGIES, INC. [CA/CA]; Sunnybrook HSC, Room S-115, 2075 Bayview Avenue, Toronto, Ontario M4N 3M5 (CA).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): WRIGHT, Jim, A. [CA/CA]; Apartment 902, 5418 Yonge Street, Toronto, Ontario M4N 6X4 (CA). YOUNG, Aiping, H. [CA/CA]; Apartment 508, 88 Grandview Way, Toronto, Ontario M2N 6V4 (CA). LEE, Yoon, S. [CA/CA]; Apartment 1412, 10 Grenoble Drive, Don Mills, Ontario M3C 1C7 (CA).

(74) Agent: GRAVELLE, Micheline; Bereskin & Parr, 40 floor, 40 King Street West, Toronto, Ontario M5H 3Y2 (CA).

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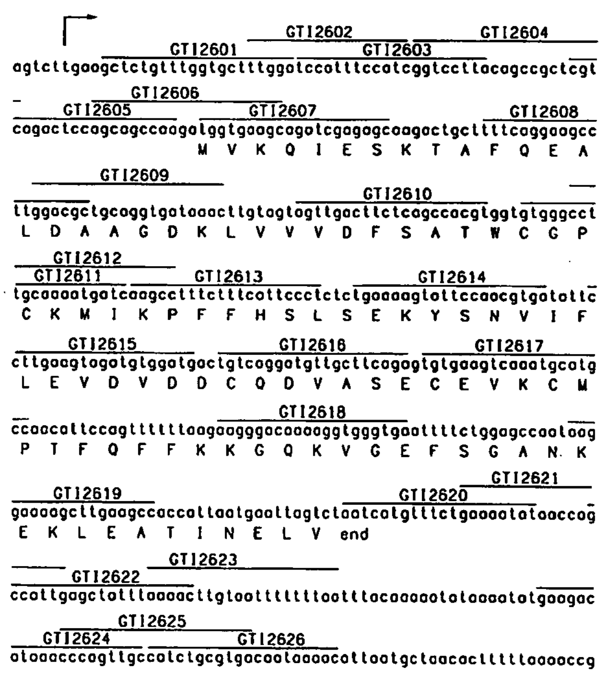
(57) Abstract

This invention relates to oligonucleotides complementary to the thioredoxin and thioredoxin reductase genes which modulate tumor cell growth in mammals. This invention is also related to methods of using such compounds in inhibiting the growth of tumor cells in mammals. This invention also relates to pharmaceutical compositions comprising a pharmaceutically acceptable excipient and an effective amount of a compound of this invention.



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OLIGONUCLEOTIDE SEQUENCES COMPLEMENTARY TO THIOREDOXIN OR THIOREDOXIN REDUCTASE GENES AND METHODS OF USING SAME TO MOLULATE CELL GROWTH

REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Serial No. 60/073,196 filed January 30, 1998, which application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to oligonucleotides that are complementary to the thioredoxin and thioredoxin reductase genes which modulate tumor cell growth in mammals. This invention is also related to methods of using such compounds in inhibiting the growth of tumor cells in mammals. This invention also relates to pharmaceutical compositions comprising a pharmaceutically acceptable excipient and an effective amount of a compound of this invention.

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All of the above publications, patent applications and patents are herein incorporated by reference in their entirety to the same extent as if each individual publication, patent application or patent was specifically and individually indicated to be incorporated by reference in its entirety.

State of the Art

Thioredoxin is a small ubiquitous redox protein originally identified as a reducing cofactor for ribonucleotide reductase which is essential for DNA synthesis[1]. Thioredoxin and thioredoxin reductase comprise the thioredoxin system. Thioredoxin reductase is a selenocysteine containing flavoenzyme which uses NADPH as a proton donor to reduce thioredoxin which in turn reduces other proteins and therefore influences their functions.

In recent years, mammalian thioredoxin has been implicated in a variety of other biochemical pathways. For example, it modulates redox properties of transcription factors by dithiol disulfide exchanges, which alter their DNA binding characteristics. Transcription factors such as NF-κB[3], BZLFI[4] and TFIIIC[5] are directly regulated, while AP-1 activation is mediated indirectly through the nuclear redox factor Ref-1 which is further reduced by thioredoxin[6]. In addition, thioredoxin has been shown to facilitate refolding of disulfide-containing proteins, to activate the glucocorticoid or interleukin-2-receptors, to inhibit human immunodeficiency virus expression in macrophages, to reduce H_2O_2 scavenge free radicals, to protect cells against oxidative stress and to be an early pregnancy factor.

Cloned human thioredoxin has been shown to be similar to a growth factor termed adult T-cell leukemia-derived factor, released by HTLV-1 transformed T cells[7]. It utilizes a pathway for secretion. Extracellularly expressed thioredoxin stimulates the proliferation of normal fibroblasts, lymphoid cells and a number of human solid tumor cell lines[8 & 9]. Redox-inactive forms have been used to show that the growth stimulation requires a redox activity of thioredoxin[9]. The growth stimulation by thioredoxin appears to be induced indirectly through sensitizing cells to other growth factors[10]. Subsequently, thioredoxin has been reported to be

over-expressed in some primary tumors such as lung, colon, cervical and hepatocellular carcinoma[11-14]. Furthermore, human breast cancer cells transfected with wild-type thioredoxin cDNA have shown increased tumor growth[15], decreased spontaneous apoptosis *in vivo*[16] and decreased sensitivity to apoptosis induced by a variety of anticancer therapeutic compounds[16]. On the other hand, cells transfected with dominant-negative, redox-inactive mutant thioredoxin have shown reduced anchorage-independent growth *in vitro* and inhibition of tumor growth *in vivo*[15].

Thioredoxin reductase has been shown to be overexpressed by a number of human tumors[12]. Inhibition of cellular thioredoxin reductase by antitumor quinones[17 & 18], nitrosoureas[19] and 13-*cis*-retinoic acid[20] have led to a decreased activity of the thioredoxin system and consequent contribution to the growth inhibitory activity.

Antisense oligonucleotides have been utilized to inhibit gene expression in a target-specific manner by sequence-specific hybridization to target mRNA[2]. Antisense oligonucleotide-mediated repression of oncogenes has revealed that these compounds may be useful for identifying mechanisms governing oncogenesis[21] and may also be promising as novel therapeutic compounds for the treatment of cancer[22]. Therefore, it would be desirable to identify antisense oligonucleotides directed against thioredoxin and thioredoxin reductase which act to inhibit the expression of thioredoxin or thioredoxin reductase with higher specificity and with less toxicity.

SUMMARY OF THE INVENTION

This invention is directed to antisense oligonucleotides which modulate the expression of the thioredoxin and thioredoxin reductase genes in tumor cells in

mammals and pharmaceutical compositions comprising such antisense oligonucleotides. This invention is also related to methods of using such antisense oligonucleotides for inhibiting the growth and metastasis of tumor cells in mammals.

Accordingly, in one of its composition aspects, this invention is directed to an antisense oligonucleotide, which oligonucleotide comprises from about 3 to about 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal. The antisense oligonucleotide may be nuclease resistant and may have one or more phosphorothioate internucleotide linkages. The antisense oligonucleotide may further comprise additional nucleotides which are not complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA.

In another of its composition aspects, this invention is directed to an antisense oligonucleotide comprising from about 17 to about 50 nucleotides, wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 2601 - 2626 [SEQ ID NOs:1 - 26] as set forth in Table 1.

In another of its composition aspects, this invention is directed to an antisense oligonucleotide comprising from about 20 to about 50 nucleotides, wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 3001 - 3040 [SEQ ID NOs:27 - 66] as set forth in Table 2.

In still another of its composition aspects, this invention is directed to a pharmaceutical composition comprising a pharmaceutically acceptable excipient and an effective amount of an antisense oligonucleotide, which oligonucleotide comprises from about 3 to about 50 nucleotides, which nucleotides are

complementary to the thioredoxin gene or the thioredoxin reductase gene of a mammal.

In still another of its composition aspects, this invention is directed to a pharmaceutical composition comprising a pharmaceutically acceptable excipient and an effective amount of an antisense oligonucleotide comprising from about 17 to about 50 nucleotides, wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 2601 - 2626 [SEQ ID NOs:1 - 26] as set forth in Table 1.

In still another of its composition aspects, this invention is directed to a pharmaceutical composition comprising a pharmaceutically acceptable excipient and an effective amount of an antisense oligonucleotide comprising from about 20 to about 50 nucleotides, wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 3001 - 3040 [SEQ ID NOs:27 - 66] as set forth in Table 2.

In one of its method aspects, this invention is directed to a method for inhibiting the growth of a mammalian tumor comprising, administering to a mammal suspected of having the tumor an effective amount of an antisense oligonucleotide comprising from about 3 nucleotides to about 50 nucleotides complementary to the thioredoxin gene of the mammal under conditions such that the growth of the tumor is inhibited. The antisense oligonucleotide may be administered with a chemotherapeutic agent.

In another of its method aspects, this invention is directed to a method for inhibiting the growth of a mammalian tumor comprising, administering to a mammal suspected of having the tumor an effective amount of an antisense oligonucleotide comprising from about 3 nucleotides to about 50 nucleotides

complementary to the thioredoxin reductase gene of the mammal under conditions such that the growth of the tumor is inhibited. The antisense oligonucleotide may be administered with a chemotherapeutic agent.

In another of its method aspects, this invention is directed to a method for inhibiting the metastasis of a mammalian tumor comprising, administering to a mammal suspected of having a metastatic tumor an effective amount of an antisense oligonucleotide comprising from about 3 nucleotides to about 50 nucleotides complementary to the thioredoxin gene of the mammal under conditions such that the metastasis of the tumor is inhibited. The antisense oligonucleotide may be administered with a chemotherapeutic agent.

In another of its method aspects, this invention is directed to a method for inhibiting the metastasis of a mammalian tumor comprising, administering to a mammal suspected of having the tumor an effective amount of an antisense oligonucleotide comprising from about 3 nucleotides to about 50 nucleotides complementary to the thioredoxin reductase gene of the mammal under conditions such that the metastasis of the tumor is inhibited. The antisense oligonucleotide may be administered with a chemotherapeutic agent.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is an autoradiograph of a Northern blot of thioredoxin mRNA in various cell lines: Human normal embryonic lung cell line (WI-38), fibrosarcoma (HT-1080), lung carcinoma (A549), ovary adenocarcinoma (SK-OV-3), hepatocellular carcinoma (Hep G2), melanoma (C8161) breast adenocarcinoma (MDA-MB-231), metastatic pancreatic adenocarcinoma (AsPC-1), colon adenocarcinoma (HT-29), cervical carcinoma (HeLa S3).

Fig. 1B is a photograph of a Western blot of thioredoxin protein expressed in various cell lines. The lower panel shows the total protein loaded in each lane.

Fig 2 is the cDNA sequence of thioredoxin [SEQ ID NOs: 67 and 68]. The hybridization sites to which the 26 different antisense oligonucleotides anneal is indicated.

Figs. 3A - 3F are graphs showing the percentage inhibition of various human cancer cell line's colony forming ability after treatment with 26 different antisense oligonucleotides complementary to the thioredoxin cDNA. The cell lines tested were human colon cancer HT-29 (Fig. 3A), human breast cancer cell line MDA-MB-231(Fig. 3B), human liver cancer cell line HepG2 (Fig. 3C), human melanoma cell line A2058 (Fig. 3D), human ovary cancer cell line SK-OV-3 (Fig. 3E) and human lung cancer cell line A549 (Fig. 3F).

Fig. 4A is a graph showing the decreased thioredoxin mRNA levels in the human liver cancer cell line HepG2 following treatment with 6 antisense oligonucleotides complementary to the thioredoxin mRNA as a percentage of the mRNA levels in the untreated cell line.

Fig. 4B is a graph showing the decreased thioredoxin mRNA levels in the human breast cancer cell line MDA-MB-231 following treatment with 6 antisense oligonucleotides complementary to the thioredoxin mRNA as a percentage of the mRNA levels in the untreated cell line.

Fig. 5A is a photograph of a Western blot showing the level of thioredoxin protein expressed in the human colon cancer cell line HT-29 following treatment with the indicated antisense oligonucleotides.

Fig. 5B is a photograph of a Western blot showing the level of thioredoxin protein expressed in the human breast cancer cell line MDA-MB-231 following treatment with the indicated antisense oligonucleotides.

Fig. 5C is a photograph of a Western blot showing the level of thioredoxin protein expressed in the human colon cancer cell line HT-29, the human breast cancer cell line MDA-MB-231, and the human liver cancer cell line HepG2 following treatment with the antisense oligonucleotide 2601 [SEQ ID NO:1]. The lower panel shows that protein loading was consistent across the panel.

Fig. 6A is a chart of the size of a tumor in nude mice over time after intravenous treatment of the mice every second day with the indicated antisense oligonucleotides.

Fig. 6B is a graph of the weight of the tumor removed from the nude mice approximately 10 days after intravenous treatment of the mice every second day with the indicated antisense oligonucleotides.

Fig. 6C is photograph of a Western blot showing the level of thioredoxin protein expression in the human colon cancer HT-29 tumors excised from the nude mice approximately 10 days after intravenous treatment of the mice every second day with the indicated antisense oligonucleotides. A part of the blot stained with India ink is shown below to demonstrate protein loading.

Fig. 7 is a autoradiograph of a Northern blot showing the level of thioredoxin reductase mRNA expressed in the indicated tumor cell lines.

Figs. 8A - 8D are graphs showing the percentage of inhibition of various human cancer cell line's colony forming ability after treatment with 40 different

antisense oligonucleotides complementary to the thioredoxin reductase mRNA. The cell lines tested were human breast cancer cell line MDA-MB-231(Fig. 8A), human melanoma A2058 (Fig. 8B), human liver cancer HepG2 (Fig. 8C) and human pancreatic cancer SU.86.86 (Fig. 8D).

Figs. 9A and 9B are graphs showing the level of expression of thioredoxin reductase mRNA in cell lines after treatment with the indicated antisense oligonucleotides as a percentage of the level of mRNA in the untreated cell line. Fig. 9A is the human colon cancer cell line HT-29 and Fig. 9B is the human breast cancer cell line MDA-MB-231.

Fig. 10 is a photograph of a Western blot showing the level of thioredoxin reductase protein expression in human pancreatic cancer cell line AsPC-1 following treatment with antisense oligonucleotides 3014 and 3037 [SEQ ID NOs: 40 and 63].

Fig. 11A is a chart showing the size of a human tumor in nude mice over time after intravenous treatment of the mice every second day with the indicated antisense oligonucleotides.

Fig. 11B is a graph of the weight of the human tumor removed from the mice approximately 10 days after intravenous treatment of the mice every second day with the indicated antisense oligonucleotides.

Fig. 12 is photograph of a Western blot showing the level of thioredoxin reductase protein expression in the human colon cancer HT-29 tumors excised from the nude mice approximately 10 days after intravenous treatment of the mice every second day with the indicated antisense oligonucleotides.

DETAILED DESCRIPTION OF THE INVENTION

Definitions:

As used herein, the following terms have the following meanings:

The term "antisense oligonucleotide" as used herein means a nucleotide sequence that is complementary to the desired mRNA. Preferably, the antisense oligonucleotide is complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA. It is contemplated that the antisense oligonucleotide may be complementary to any of the 5' untranslated region of the mRNA, the coding region or the 3' untranslated region of the mRNA.

The term "oligonucleotide" refers to an oligomer or polymer of nucleotide or nucleoside monomers consisting of naturally occurring bases, sugars, and inter-sugar (backbone) linkages. The term also includes modified or substituted oligomers comprising non-naturally occurring monomers or portions thereof, which function similarly. Such modified or substituted oligomers may be preferred over naturally occurring forms because of the properties such as enhanced cellular uptake, or increased stability in the presence of nucleases. The term also includes chimeric oligonucleotides which contain two or more chemically distinct regions. For example, chimeric oligonucleotides may contain at least one region of modified nucleotides that confer beneficial properties (e.g. increased nuclease resistance, increased uptake into cells) or two or more oligonucleotides of the invention may be joined to form a chimeric oligonucleotide.

The antisense oligonucleotides of the present invention may be ribonucleic or deoxyribonucleic acids and may contain naturally occurring or synthetic monomeric bases, including adenine, guanine, cytosine, thymine and uracil. The

oligonucleotides may also contain modified bases such as xanthine, hypoxanthine, 2-aminoadenine, 6-methyl, 2-propyl and other alkyl adenines, 5-halo uracil, 5-halo cytosine, 6-aza uracil, 6-aza cytosine and 6-aza thymine, pseudo uracil, 4-thiouracil, 8-halo adenine, 8-aminoadenine, 8-thiol adenine, 8-thiolalkyl adenines, 8-hydroxyl adenine and other 8-substituted adenines, 8-halo guanines, 8-amino guanine, 8-thiol guanine, 8-thioalkyl guanines, 8-hydroxyl guanine and other 8-substituted guanines, other aza and deaza uracils, thymidines, cytosines or guanines, 5-trifluoromethyl uracil and 5-trifluoro cytosine. The modifications may also include attachment of other chemical groups such as methyl, ethyl, propyl groups to the various parts of the oligonucleotides including the sugar, base or backbone components.

The antisense oligonucleotides of the invention may also comprise modified phosphorus oxygen heteroatoms in the phosphate backbone, short chain alkyl or cycloalkyl intersugar linkages or short chain heteroatom or heterocyclic intersugar linkages. For example, the antisense oligonucleotides may contain methyl phosphonates, phosphorothioates, phosphorodithioates, phosphotriesters, and morpholino oligomers. In one embodiment of the invention, the antisense oligonucleotides comprise phosphorothioate bonds linking between the four to six 3'-terminus nucleotides. In another embodiment, the phosphorothioate bonds link all the nucleotides. The antisense oligonucleotides may also have sugar mimetics.

The antisense oligonucleotides of the invention may also comprise nucleotide analogues wherein the structure of the nucleotide is fundamentally altered. An example of such an oligonucleotide analogue is a peptide nucleic acid (PNA) wherein the deoxyribose (or ribose) phosphate backbone in DNA (or RNA) is replaced with a polyamide backbone which is similar to that found in peptides (Nielsen et al.[29]; Good and Nielsen[30]; Buchardt, deceased, et al.[31], U.S. Patent No. 5,766,855; Buchardt, deceased, et al.[32], U.S. Patent No. 5,719,262). PNA

analogues have been shown to be resistant to degradation by enzymes and to have extended lives *in vivo* and *in vitro*. PNAs also bind more strongly to a complementary DNA sequence than to a naturally occurring nucleic acid molecule due to the lack of charge repulsion between the PNA strand and the DNA strand.

The oligonucleotides of the present invention may also include other nucleotides comprising polymer backbones, cyclic backbones, or acyclic backbones. For example, the nucleotides may comprise morpholino backbone structures (U.S. Patent No. 5,034,506[33]).

The oligonucleotides of the present invention are "nuclease resistant" when they have either been modified such that they are not susceptible to degradation by DNA and RNA nucleases or alternatively they have been placed in a delivery vehicle which in itself protects the oligonucleotide from DNA or RNA nucleases. Nuclease resistant oligonucleotides include, for example, methyl phosphonates, phosphorothioates, phosphorodithioates, phosphotriesters, and morpholino oligomers. Suitable delivery vehicles for conferring nuclease resistance include, for example liposomes.

The oligonucleotides of the present invention may also contain groups, such as groups for improving the pharmacokinetic properties of an oligonucleotides, or groups for improving the pharmacodynamic properties of an oligonucleotide. Preferably, the oligonucleotides do not contain reporter groups or labels, such as fluorescent dyes or radioactive labels.

The antisense oligonucleotides are preferably selected from the sequence complementary to the thioredoxin or thioredoxin reductase genes such that the sequence exhibits the least likelihood of showing duplex formation, hair-pin formation, and homooligomer/sequence repeats but has a high to moderate

potential to bind to the thioredoxin or thioredoxin reductase gene sequences. These properties may be determined using the computer modeling program OLIGO Primer Analysis Software, Version 5.0 (distributed by National Biosciences, Inc., Plymouth, MN). This computer program allows the determination of a qualitative estimation of these five parameters.

Alternatively, the antisense oligonucleotides may also be selected on the basis that the sequence is highly conserved for either the thioredoxin or thioredoxin reductase gene between two or more mammalian species. These properties may be determined using the BLASTN program (Altschul, et al.[34]) of the University of Wisconsin Computer group (GCG) software (Devereux J. et al.[35]) with the National Center for Biotechnology Information (NCBI) databases.

The antisense oligonucleotides may include mutations, such as substitutions, insertions and deletions. Preferably there will be less that 10% of the sequence having mutations.

The antisense oligonucleotides generally comprise from at least about 3 nucleotides or nucleotide analogs, preferably from about 3 to about 100 nucleotides or nucleotide analogs, more preferably, from about 3 to about 50 nucleotides or nucleotide analogs, most preferably from about 17 to about 35 nucleotide or nucleotide analogs.

Preferably, the antisense oligonucleotides comprise the sequences set forth in Tables 1 and 2 (below).

Table 1

Antisense oligonucleotides having a sequence complementary to the human thioredoxin mRNA

SEQ ID No:	Name	Sequence 5'-3'	Tm (°C)	ΔG (kcal/mol)
1	2601	TCC AAA GCA CCA AAC AGA GC	61.9	-38.2
2	2602	GAT GGA AAT GGA TCC AA	50.7	-31.6
3	2603	TAA GGA CCG ATG GAA ATG GA	61.2	-38.8
4	2604	GAC GAG CGG CTG TAA GGA CC	65.4	-41.0
5	2605	TTG GCT GCT GGA GTC TGA CG	65.2	-39.3
6	2606	GCT TCA CCA TCT TGG CTG CT	63.5	-39.3
7	2607	GCT CTC GAT CTG CTT CAC CA	61.7	-37.7
8	2608	GCG TCC AAG GCT TCC TGA AA	66.0	-41.4
9	2609	GTT TAT CAC CTG CAG CGT CC	61.4	-38.3
10	2610	ACG TGG CTG AGA AGT CAA CT	57.7	-35.7
11	2611	GAT CAT TTT GCA AGG CCC AC	63.7	-39.8
12	2612	GGC TTG ATC ATT TTG CAA GG	61.7	-38.9
13	2613	AGG GAA TGA AAG AAA GGC TT	58.7	-38.4
14	2614	TCA CGT TGG AAT ACT TTT CA	54.7	-34.7
15	2615	CAT CCA CAT CTA CTT CAA GG	53.2	-33.8
16	2616	TCT GAA GCA ACA TCC TGA CA	57.4	-34.8

SEQ ID No:	Name	Sequence 5'-3'	Tm (°C)	ΔG (kcal/mol)
17	2617	GGCATG CAT TTG ACT TCA CA	60.7	-36.8
18	2618	TCA CCC ACC TTT TGT CCC TT	62.5	-39.1
19	2619	GGC TTC AAG CTT TTC CTT	55.4	-35.3
20	2620	ATA TTT TCA GAA ACA TGA TT	47.3	-31.8
21	2621	CAA TGG CTG GTT ATA TTT TC	53.9	-35.5
22	2622	GTT TTA AAT AGC TCA ATG GC	53.6	-35.6
23	2623	TTA AAA AAA TTA CAA GTT TT	46.7	-32.4
24	2624	GCA ACT GGG TTT ATG TCT TC	55.5	-35.4
25	2625	TCA CGC AGA TGG CAA CTG GG	68.2	-41.0
26	2626	GTT TTA TTG TCA CGC AGA TG	54.7	-34.6

Table 2

Antisense oligonucleotides complementary to the sequence of the human thioredoxin reductase mRNA

SEQ ID No:	Name	Sequence 5'-3'	Tm (°C)	ΔG (kcal/mol)
27	3001	CCC GAC GCA GAG CTT ACA AG	64.4	-40.4
28	3002	GCT CGC GGC TTT GTC TGG TT	68.4	-42.8
29	3003	CCG TCC CCC GCG TGC TCC CA	80.0	-49.9
30	3004	GCT GTC GTC CCC GCC GGC AG	77.9	-48.4

SEQ ID No:	Name	Sequence 5'-3'	Tm (°C)	ΔG (kcal/mol)
31	3005	CTG CTG CAC CCA GGC GCA AT	72.1	-44.3
32	3006	TCT TCC CTT CCC CGA GAC GC	69.4	-43.7
33	3007	CCG TCT GCT CAG ACA CGC CT	66.7	-40.4
34	3008	CCG CAC ACG CCA CGA AGC TG	73.5	-44.5
35	3009	GAA GCT TTG TGT GAC CGG GT	63.1	-39.0
36	3010	TCA GGG CCC GAC CGT CCT CA	73.5	-44.9
37	3011	GCA GAT CGG TTT CCG CGG CC	74.8	-47.4
38	3012	GGT TGG ACC ATG GCC GCC TA	70.8	-44.3
39	3013	AGG GCC GTT CAT TTT TAG TA	58.2	-38.3
40	3014	AGA TCT TCA GGG CCG TTC AT	61.9	-39.1
41	3015	AGC AGC TGC CAG ACC TCC TG	65.9	-40.3
42	3016	CAA GAG GGG TGG GAG TGA CA	63.5	-38.5
43	3017	TTT CGA GAG TCT TGC AGG GC	63.7	-39.6
44	3018	CTC GGT AGC CCC AAT TCA AA	63.6	-40.7
45	3019	TTG TCA CCA GGG ATG CCC AA	67.4	-40.8
46	3020	TCC AAA GCG ACA TAG GAT GC	61.9	-38.8
47	3021	CCT ATT GCC AGC ATC ACC GT	64.2	-40.0
48	3022	CTG GAT TGC AAC TGG GGT GA	64.6	-39.3
49	3023	CCT CAG AAA GGC CAC AAG CA	64.4	-39.7

SEQ ID No:	Name	Sequence 5'→3'	Tm (°C)	ΔG (kcal/mol)
50	3024	TTG AGC GCA GCT GCA AAG CC	70.5	-43.5
51	3025	GAG CGC TTG GTC ACA GAC AA	62.6	-37.8
52	3026	AAC AGC ATC CAC ACT GGG GC	66.1	-40.2
53	3027	GCA CGG AAA CGA GCC AGT GG	69.3	-42.5
54	3028	ACG CAG GTG CCA AGA GCC CA	71.6	-43.8
55	3029	GTG ACC CCA GTG TGA TGC TG	62.1	-36.9
56	3030	TCG ATG CCC TGC CAA ATG TC	67.2	-41.2
57	3031	ACA GTT GTT CCA TCA CCG CC	63.7	-38.9
58	3032	TCC CTT CCA TGC AAC AAG AC	61.4	-37.8
59	3033	TTT CCC GGG ACA AGC CTA CA	66.2	-41.7
60	3034	GCA CAC AGG GGC AAA TTT GG	66.8	-41.4
61	3035	CTA CCA AAT GCC AGG CAA TG	62.4	-39.2
62	3036	TGT TTC TCC CCC ATT TCT GG	63.1	-39.6
63	3037	GTT CCC TGA GGT GGC CCA GA	67.6	-41.5
64	3038	ACG GTC AGG GGC TCT GCT GC	70.4	-43.2
65	3039	ATG AGG ACG TGA GGC AGA GC	63.1	-38.6
66	3040	TGG TCA ACT GCC TCA ATT GC	62.5	-38.1

In Tables 1 and 2 the "Tm" is the melting temperature of an oligonucleotide duplex calculated according to the nearest-neighbour thermodynamic values. At this temperature 50% of nucleic acid molecules are in duplex and 50% are denatured. The

"ΔG" is the free energy of the oligonucleotide, which is a measurement of an oligonucleotide duplex stability.

The term "alkyl" refers to monovalent alkyl groups preferably having from 1 to 20 carbon atoms and more preferably 1 to 6 carbon atoms. This term is exemplified by groups such as methyl, ethyl, *n*-propyl, *iso*-propyl, *n*-butyl, *iso*-butyl, *n*-hexyl, and the like.

The term "aryl" refers to an unsaturated aromatic carbocyclic group of from 6 to 14 carbon atoms having a single ring (e.g., phenyl) or multiple condensed (fused) rings (e.g., naphthyl or anthryl). Preferred aryls include phenyl, naphthyl and the like.

The term "cycloalkyl" refers to cyclic alkyl groups of from 3 to 20 carbon atoms having a single cyclic ring or multiple condensed rings. Such cycloalkyl groups include, by way of example, single ring structures such as cyclopropyl, cyclobutyl, cyclopentyl, cyclooctyl, and the like, or multiple ring structures such as adamantanyl, and the like.

The term "halo" or "halogen" refers to fluoro, chloro, bromo and iodo and preferably is either fluoro or chloro.

The term "thiol" refers to the group -SH.

As to any of the above groups which contain one or more substituents, it is understood, of course, that such groups do not contain any substitution or substitution patterns which are sterically impractical and/or synthetically non-

feasible. In addition, the compounds of this invention include all stereochemical isomers arising from the substitution of these compounds.

The term "pharmaceutically acceptable salt" refers to salts which retain the biological effectiveness and properties of the antisense oligonucleotides of this invention and which are not biologically or otherwise undesirable. In many cases, the antisense oligonucleotides of this invention are capable of forming acid and/or base salts by virtue of the presence of amino and/or carboxyl groups or groups similar thereto.

Pharmaceutically acceptable base addition salts can be prepared from inorganic and organic bases. Salts derived from inorganic bases, include by way of example only, sodium, potassium, lithium, ammonium, calcium and magnesium salts. Salts derived from organic bases include, but are not limited to, salts of primary, secondary and tertiary amines, such as alkyl amines, dialkyl amines, trialkyl amines, substituted alkyl amines, di(substituted alkyl) amines, tri(substituted alkyl) amines, alkenyl amines, dialkenyl amines, trialkenyl amines, substituted alkenyl amines, di(substituted alkenyl) amines, tri(substituted alkenyl) amines, cycloalkyl amines, di(cycloalkyl) amines, tri(cycloalkyl) amines, substituted cycloalkyl amines, disubstituted cycloalkyl amine, trisubstituted cycloalkyl amines, cycloalkenyl amines, di(cycloalkenyl) amines, tri(cycloalkenyl) amines, substituted cycloalkenyl amines, disubstituted cycloalkenyl amine, trisubstituted cycloalkenyl amines, aryl amines, diaryl amines, triaryl amines, heteroaryl amines, diheteroaryl amines, triheteroaryl amines, heterocyclic amines, diheterocyclic amines, triheterocyclic amines, mixed di- and tri-amines where at least two of the substituents on the amine are different and are selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, cycloalkyl, substituted cycloalkyl, cycloalkenyl, substituted cycloalkenyl, aryl,

heteroaryl, heterocyclic, and the like. Also included are amines where the two or three substituents, together with the amino nitrogen, form a heterocyclic or heteroaryl group.

Examples of suitable amines include, by way of example only, isopropylamine, trimethylamine, diethylamine, tri(*iso*-propyl)amine, tri(*n*-propyl)amine, ethanolamine, 2-dimethylaminoethanol, tromethamine, lysine, arginine, histidine, caffeine, procaine, hydrabamine, choline, betaine, ethylenediamine, glucosamine, N-alkylglucamines, theobromine, purines, piperazine, piperidine, morpholine, N-ethylpiperidine, and the like. It should also be understood that other carboxylic acid derivatives would be useful in the practice of this invention, for example, carboxylic acid amides, including carboxamides, lower alkyl carboxamides, dialkyl carboxamides, and the like.

Pharmaceutically acceptable acid addition salts may be prepared from inorganic and organic acids. Salts derived from inorganic acids include hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid, and the like. Salts derived from organic acids include acetic acid, propionic acid, glycolic acid, pyruvic acid, oxalic acid, malic acid, malonic acid, succinic acid, maleic acid, fumaric acid, tartaric acid, citric acid, benzoic acid, cinnamic acid, mandelic acid, methanesulfonic acid, ethanesulfonic acid, *p*-toluene-sulfonic acid, salicylic acid, and the like.

The term "thioredoxin gene" refers to any gene which encodes a protein that is capable of acting as a hydrogen donor for ribonucleotide reductase or methionine sulfoxide reductase. Preferably the thioredoxin gene encodes a protein capable of modulating the redox properties of transcription factors such as NF-κB, BZLF1, TFIIIC and AP-1 and alters their DNA binding characteristics. Other

functions which the protein may have, include but are not limited to the ability to facilitate refolding of disulfide containing proteins, to activate glucocorticoid or interleukin-2 receptors, or to inhibit immunodeficiency virus expression in macrophages, to reduce intracellular H_2O, to scavenge free radicals, to protect cells against oxidative stress and to act as an essential component of the early pregnancy factor. Preferably, the thioredoxin gene encodes a protein which is capable of stimulating the proliferation of normal fibroblasts, lymphoid cells, and a number of human solid tumor cell lines and is capable of stimulating tumor growth and decreasing apoptosis when overexpressed in human tumors.

The term "thioredoxin reductase gene" refers to any gene which encodes a protein that is capable of catalyzing NADPH-dependent reduction of thioredoxin.

The term “complementary to” means that the antisense oligonucleotide sequence is capable of binding to the target sequence, ie the thioredoxin gene (or mRNA) or the thioredoxin reductase gene (or mRNA). Preferably the antisense oligonucleotide sequence has at least about 75% identity with the target sequence, preferably at least about 90% identity and most preferably at least about 95% identity with the target sequence allowing for gaps or mismatches of several bases. Identity can be determined, for example, by using the BLASTN program of the University of Wisconsin Computer Group (GCG) software. Preferably the antisense oligonucleotide sequence hybridizes to the thioredoxin or thioredoxin reductase mRNA with a melting temperature of at least 45°C, more preferably at least about 50°C and most preferably at least about 55°C as determined by the OLIGO program described herein.

The term “inhibiting growth” means a reduction in the growth of at least one tumor cell type by at least 10%, more preferably of at least 50% and most

preferably of at least 75%. The reduction in growth can be determined for tumor cells by measuring the size of the tumor in nude mice or the inability of the tumor cells to form colonies *in vitro*.

The term "mammal" or "mammalian" means all mammals including humans, ovines, bovines, equines, swine, canines, felines and mice, etc.

A "mammal suspected of having a tumor" means that the mammal may have a proliferative disorder or tumor or has been diagnosed with a proliferative disorder or tumor or has been previously diagnosed with a proliferative disorder or tumor, the tumor has been surgically removed and the mammal is suspected of harboring some residual tumor cells.

Preparation of the Antisense Oligonucleotides

The antisense oligonucleotides of the present invention may be prepared by conventional and well-known techniques. For example, the oligonucleotides may be prepared using solid-phase synthesis and in particular using commercially available equipment such as the equipment available from Applied Biosystems Canada Inc., Mississauga, Canada. The oligonucleotides may also be prepared by enzymatic digestion of the naturally occurring thioredoxin or thioredoxin reductase gene by methods known in the art.

Isolation and Purification of the Antisense Oligonucleotides

Isolation and purification of the antisense oligonucleotides described herein can be effected, if desired, by any suitable separation or purification such as, for example, filtration, extraction, crystallization, column chromatography, thin-layer chromatography, thick-layer chromatography, preparative low or high-pressure

liquid chromatography or a combination of these procedures. However, other equivalent separation or isolation procedures could, of course, also be used.

An expression vector comprising the antisense oligonucleotide sequence may be constructed having regard to the sequence of the oligonucleotide and using procedures known in the art.

Vectors can be constructed by those skilled in the art to contain all the expression elements required to achieve the desired transcription of the antisense oligonucleotide sequences. Therefore, the invention provides vectors comprising a transcription control sequence operatively linked to a sequence which encodes an antisense oligonucleotide. Suitable transcription and translation elements may be derived from a variety of sources, including bacterial, fungal, viral, mammalian or insect genes. Selection of appropriate elements is dependent on the host cell chosen.

Reporter genes may be included in the vector. Suitable reporter genes include β-galactosidase (e.g. lacZ), chloramphenicol, acetyl-transferase, firefly luciferase, or an immunoglobulin or portion thereof. Transcription of the antisense oligonucleotide may be monitored by monitoring for the expression of the reporter gene.

The vectors can be introduced into cells or tissues by any one of a variety of known methods within the art. Such methods can be found generally described in Sambrook et al.[24]; Ausubel et al.[25]; Chang et al.[36]; Vega et al.[37]; and Vectors: A Survey of Molecular Cloning Vectors and Their Uses[38] and include, for example, stable or transient transfection, lipofection, electroporation and infection with recombinant viral vectors.

Introduction of nucleic acids by infection offers several advantages. Higher efficiency and specificity for tissue type can be obtained. Viruses typically infect and propagate in specific cell types. Thus, the virus' specificity may be used to target the vector to specific cell types *in vivo* or within a tissue or mixed culture of cells. Viral vectors can also be modified with specific receptors or ligands to alter target specificity through receptor mediated events.

The oligonucleotide of the invention may be insolubilized. For example, the oligonucleotide may be bound to a suitable carrier. Examples of suitable carriers are agarose, cellulose, dextran, Sephadex, Sepharose, carboxymethyl cellulose polystyrene, filter paper, ion-exchange resin, plastic film, plastic tube, glass beads, polyamine-methyl vinyl-ether-maleic acid copolymer, amino acid copolymer, ethylene-maleic acid copolymer, nylon, silk etc. The carrier may in the shape of, for example, a tube, test plate, beads disc, sphere etc.

The insoubilized oligonucleotide may be prepared by reacting the material with the suitable insoluble carrier using known chemical or physical methods, for example, cyanogen bromide coupling.

It is contemplated that the oligonucleotide of this invention may be a ribozyme which cleaves the mRNA. The ribozyme preferably has a sequence homologous to a sequence of an oligonucleotide of the invention and the necessary catalytic center for cleaving the mRNA. For example, a homologous ribozyme sequence may be selected which destroys the thioredoxin or thioredoxin reductase mRNA. The ribozyme type utilized in the present invention may be selected from types known in the art. Several ribozyme structural families have been identified including Group I introns, RNase P, the hepatitis delta virus ribozyme, hammerhead ribozymes and the hairpin ribozyme originally derived from the

negative strand of the tobacco ringspot virus satellite RNA (sTRSV) (Sullivan 1994, U.S. Patent No. 5,225,347[39]). Hammerhead and hairpin ribozyme motifs are most commonly adapted for trans cleavage of mRNAs for gene therapy (Sullivan 1994). Hairpin ribozymes are preferably used in the present invention. In general, the ribozyme is from 30 to 100 nucleotides in length.

Pharmaceutical Formulations

When employed as pharmaceuticals, the antisense oligonucleotides are usually administered in the form of pharmaceutical compositions. These compounds can be administered by a variety of routes including oral, rectal, transdermal, subcutaneous, intravenous, intramuscular, and intranasal. These compounds are effective as both injectable and oral compositions. Such compositions are prepared in a manner well known in the pharmaceutical art and comprise at least one active compound. The pharmaceutical composition is, for example, administered intravenously. It is contemplated that the pharmaceutical composition may be administered directly into the tumor to be treated.

This invention also includes pharmaceutical compositions which contain, as the active ingredient, one or more of the antisense oligonucleotides associated with pharmaceutically acceptable carriers or excipients. In making the compositions of this invention, the active ingredient is usually mixed with an excipient, diluted by an excipient or enclosed within such a carrier which can be in the form of a capsule, sachet, paper or other container. When the excipient serves as a diluent, it can be a solid, semi-solid, or liquid material, which acts as a vehicle, carrier or medium for the active ingredient. Thus, the compositions can be in the form of tablets, pills, powders, lozenges, sachets, cachets, elixirs, suspensions, emulsions, solutions, syrups, aerosols (as a solid or in a liquid medium), ointments containing, for example, up to 10% by weight of the active compound, soft and

hard gelatin capsules, suppositories, sterile injectable solutions, and sterile packaged powders.

In preparing a formulation, it may be necessary to mill the active compound to provide the appropriate particle size prior to combining with the other ingredients. If the active compound is substantially insoluble, it ordinarily is milled to a particle size of less than 200 mesh. If the active compound is substantially water soluble, the particle size is normally adjusted by milling to provide a substantially uniform distribution in the formulation, e.g. about 40 mesh.

Some examples of suitable excipients include lactose, dextrose, sucrose, sorbitol, mannitol, starches, gum acacia, calcium phosphate, alginates, tragacanth, gelatin, calcium silicate, microcrystalline cellulose, polyvinylpyrrolidone, cellulose, sterile water, syrup, and methyl cellulose. The formulations can additionally include: lubricating agents such as talc, magnesium stearate, and mineral oil; wetting agents; emulsifying and suspending agents; preserving agents such as methyl- and propylhydroxy-benzoates; sweetening agents; and flavoring agents. The compositions of the invention can be formulated so as to provide quick, sustained or delayed release of the active ingredient after administration to the patient by employing procedures known in the art.

The compositions are preferably formulated in a unit dosage form, each dosage containing from about 3mg to about 3g, more usually about 10 mg to about 1.5 g, of the active ingredient. The term "unit dosage forms" refers to physically discrete units suitable as unitary dosages for human subjects and other mammals, each unit containing a predetermined quantity of active material calculated to produce the desired therapeutic effect, in association with a suitable pharmaceutical excipient.

The antisense oligonucleotide is effective over a wide dosage range and is generally administered in a pharmaceutically effective amount. An effective amount is that amount which when administered alleviates the symptoms. Preferably the effective amount is that amount able to inhibit tumor cell growth. Preferably the effective amount is from about 0.1 mg/kg body weight to about 20 mg/kg body weight. It will be understood, however, that the amount of the antisense oligonucleotide actually administered will be determined by a physician, in the light of the relevant circumstances, including the condition to be treated, the chosen route of administration, the actual compound administered, the age, weight, and response of the individual patient, the severity of the patient's symptoms, and the like. The course of therapy may last from several days to several months or until diminution of the disease is achieved.

For preparing solid compositions such as tablets, the principal active ingredient/antisense oligonucleotide is mixed with a pharmaceutical excipient to form a solid preformulation composition containing a homogeneous mixture of a compound of the present invention. When referring to these preformulation compositions as homogeneous, it is meant that the active ingredient is dispersed evenly throughout the composition so that the composition may be readily subdivided into equally effective unit dosage forms such as tablets, pills and capsules.

The tablets or pills of the present invention may be coated or otherwise compounded to provide a dosage form affording the advantage of prolonged action. For example, the tablet or pill can comprise an inner dosage and an outer dosage component, the latter being in the form of an envelope over the former. The two components can be separated by an enteric layer which serves to resist disintegration in the stomach and permit the inner component to pass intact into the

duodenum or to be delayed in release. A variety of materials can be used for such enteric layers or coatings, such materials including a number of polymeric acids and mixtures of polymeric acids with such materials as shellac, cetyl alcohol, and cellulose acetate.

The liquid forms in which the novel compositions of the present invention may be incorporated for administration orally or by injection include aqueous solutions, suitably flavored syrups, aqueous or oil suspensions, and flavored emulsions with edible oils such as corn oil, cottonseed oil, sesame oil, coconut oil, or peanut oil, as well as elixirs and similar pharmaceutical vehicles.

Compositions for inhalation or insufflation include solutions and suspensions in pharmaceutically acceptable, aqueous or organic solvents, or mixtures thereof, and powders. The liquid or solid compositions may contain suitable pharmaceutically acceptable excipients as described herein. Preferably the compositions are administered by the oral or nasal respiratory route for local or systemic effect. Compositions in preferably pharmaceutically acceptable solvents may be nebulized by use of inert gases. Nebulized solutions may be inhaled directly from the nebulizing device or the nebulizing device may be attached to a face mask tent, or intermittent positive pressure breathing machine. Solution, suspension, or powder compositions may be administered, preferably orally or nasally, from devices which deliver the formulation in an appropriate manner.

Another preferred formulation employed in the methods of the present invention employs transdermal delivery devices ("patches"). Such transdermal patches may be used to provide continuous or discontinuous infusion of the antisense oligonucleotides of the present invention in controlled amounts. The construction and use of transdermal patches for the delivery of pharmaceutical

agents is well known in the art. See, for example, U.S. Patent 5,023,252[40], herein incorporated by reference. Such patches may be constructed for continuous, pulsatile, or on demand delivery of pharmaceutical agents.

Another preferred method of delivery involves "shotgun" delivery of the naked antisense oligonucleotides across the dermal layer. The delivery of "naked" antisense oligonucleotides is well known in the art. See, for example, Felgner et al.,U.S. Patent No. 5,580,859[41]. It is contemplated that the antisense oligonucleotides may be packaged in a lipid vesicle before "shotgun" delivery of the antisense oligonucleotide.

The following formulation examples illustrate representative pharmaceutical compositions of the present invention.

Formulation Example 1

Hard gelatin capsules containing the following ingredients are prepared:

Ingredient	Quantity (mg/capsule)
Active Ingredient	30.0
Starch	305.0
Magnesium stearate	5.0

The above ingredients are mixed and filled into hard gelatin capsules in 340 mg quantities.

Formulation Example 2

A tablet formula is prepared using the ingredients below:

Ingredient	Quantity (mg/tablet)

Active Ingredient	25.0
Cellulose, microcrystalline	200.0
Colloidal silicon dioxide	10.0
Stearic acid	5.0

The components are blended and compressed to form tablets, each weighing 240 mg.

Formulation Example 3

A dry powder inhaler formulation is prepared containing the following components:

Ingredient	Weight %
Active Ingredient	5
Lactose	95

The active ingredient is mixed with the lactose and the mixture is added to a dry powder inhaling appliance.

Formulation Example 4

Tablets, each containing 30 mg of active ingredient, are prepared as follows:

Ingredient	Quantity (mg/tablet)
Active Ingredient	30.0 mg
Starch	45.0 mg
Microcrystalline cellulose	35.0 mg
Polyvinylpyrrolidone (as 10% solution in sterile water)	4.0 mg
Sodium carboxymethyl starch	4.5 mg
Magnesium stearate	0.5 mg
Talc	1.0 mg
Total	120 mg

The active ingredient, starch and cellulose are passed through a No. 20 mesh U.S. sieve and mixed thoroughly. The solution of polyvinylpyrrolidone is mixed with the resultant powders, which are then passed through a 16 mesh U.S. sieve. The granules so produced are dried at 50° to 60°C and passed through a 16 mesh U.S. sieve. The sodium carboxymethyl starch, magnesium stearate, and talc, previously passed through a No. 30 mesh U.S. sieve, are then added to the granules which, after mixing, are compressed on a tablet machine to yield tablets each weighing 120 mg.

Formulation Example 5

Capsules, each containing 40 mg of medicament are made as follows:

Ingredient	Quantity (mg/capsule)
Active Ingredient	40.0 mg
Starch	109.0 mg
Magnesium stearate	1.0 mg
Total	150.0 mg

The active ingredient, starch, and magnesium stearate are blended, passed through a No. 20 mesh U.S. sieve, and filled into hard gelatin capsules in 150 mg quantities.

Formulation Example 6

Suppositories, each containing 25 mg of active ingredient are made as follows:

Ingredient	Amount
Active Ingredient	25 mg
Saturated fatty acid glycerides to	2,000 mg

The active ingredient is passed through a No. 60 mesh U.S. sieve and suspended in the saturated fatty acid glycerides previously melted using the minimum heat necessary. The mixture is then poured into a suppository mold of nominal 2.0 g capacity and allowed to cool.

Formulation Example 7

Suspensions, each containing 50 mg of medicament per 5.0 mL dose are made as follows:

Ingredient	Amount
Active Ingredient	50.0 mg
Xanthan gum	4.0 mg
Sodium carboxymethyl cellulose (11%)	
Microcrystalline cellulose (89%)	50.0 mg
Sucrose	1.75 g
Sodium benzoate	10.0 mg
Flavor and Color	q.v.
Purified water to	5.0 mL

The active ingredient, sucrose and xanthan gum are blended, passed through a No. 10 mesh U.S. sieve, and then mixed with a previously made solution of the microcrystalline cellulose and sodium carboxymethyl cellulose in water. The sodium benzoate, flavor, and color are diluted with some of the water and added with stirring. Sufficient water is then added to produce the required volume.

Formulation Example 8

Ingredient	Quantity (mg/capsule)
Active Ingredient	15.0 mg
Starch	407.0 mg
Magnesium stearate	3.0 mg
Total	425.0 mg

The active ingredient, starch, and magnesium stearate are blended, passed through a No. 20 mesh U.S. sieve, and filled into hard gelatin capsules in 425.0 mg quantities.

Formulation Example 9

A formulation may be prepared as follows:

Ingredient	Quantity
Active Ingredient	5.0 mg
Corn Oil	1.0 mL

Formulation Example 10

A topical formulation may be prepared as follows:

Ingredient	Quantity
Active Ingredient	1-10 g
Emulsifying Wax	30 g
Liquid Paraffin	20 g
White Soft Paraffin	to 100 g

The white soft paraffin is heated until molten. The liquid paraffin and emulsifying wax are incorporated and stirred until dissolved. The active ingredient is added and stirring is continued until dispersed. The mixture is then cooled until solid.

Other suitable formulations for use in the present invention can be found in *Remington's Pharmaceutical Sciences*[23].

The antisense oligonucleotides or the pharmaceutical composition comprising the antisense oligonucleotides may be packaged into convenient kits providing the necessary materials packaged into suitable containers.

The oligonucleotides and ribozymes of the invention modulate tumor cell growth. Therefore methods are provided for interfering or inhibiting tumor cell growth in a mammal comprising contacting the tumor or tumor cells with an antisense oligonucleotide of the present invention.

The term "contact" refers to the addition of an oligonucleotide, ribozyme, etc. to a cell suspension or tissue sample or to administering the oligonucleotides etc. directly or indirectly to cells or tissues within an animal.

The methods may be used to treat proliferative disorders including various forms of cancer such a leukemias, lymphomas (Hodgkins and non-Hodgkins), sarcomas, melanomas, adenomas, carcinomas of solid tissue, hypoxic tumors, squamous cell carcinomas of the mouth, throat, larynx and lung, genitourinary cancers such as cervical and bladder cancer, hematopoietic cancers, colon cancer, breast cancer, pancreatic cancer, renal cancer, brain cancer, skin cancer, liver cancer, head and neck cancers, and nervous system cancers, as well as benign lesions such as papillomas. Other proliferative disorders such as psoriasis and those involving arthrosclerosis, angiogenesis and viral infections are also included.

The oligonucleotides of the invention may also be used to treat drug resistant tumors. Examples of drug resistant tumors are tumors resistant to such chemotherapeutic agents as 5-fluorouracil, mitomycin C, methotrexate or hydroxyurea and tumors expressing high levels of P-glycoprotein which is known to confer resistance to multiple anticancer drugs such as colchicine, vinblastine and

doxorubicin; or tumors expressing multi-drug resistance protein as described by Dreeley et al.[43]. Accordingly, it is contemplated that the oligonucleotides of the present invention may be administered in conjunction with or in addition to known anticancer compounds or chemotherapeutic agents. Chemotherapeutic agents are compound which may inhibit the growth of tumors. Such agents, include, but are not limited to, 5-fluorouracil, mitomycin C, methotrexate and hydroxyurea. It is contemplated that the amount of chemotherapeutic agent may be either an effective amount, i.e. an amount sufficient to inhibit tumor growth or a less than effective amount.

The oligonucleotides of the present invention have been found to reduce the growth of tumors that are metastatic such as MDA-MB-231 breast adenocarcinoma, HT-29 colon adenocarcinoma, A549 lung carcinoma, and A2058 melanoma cancer cells. In an embodiment of the invention, a method is provided for reducing the growth of metastastic tumors in a mammal comprising administering an amount of an oligonucleotide complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA, or an oligonucleotide shown in Tables 1 and 2.

The oligonucleotides may be delivered using viral or non-viral vectors. Sequences may be incorporated into cassettes or constructs such that an oligonucleotide of the invention is expressed in a cell. Preferably, the construct contains the proper transcriptional control region to allow the oligonucleotide to be transcribed in the cell.

Therefore, the invention provides vectors comprising a transcription control sequence operatively linked to a sequence which encodes an oligonucleotide of the

invention. The present invention further provides host cells, selected from suitable eucaryotic and procaryotic cells, which are transformed with these vectors.

Suitable vectors are known and preferably contain all of the expression elements necessary to achieve the desired transcription of the sequences. Phagemids are a specific example of such beneficial vectors because they can be used either as plasmids or as bacteriophage vectors. Examples of the vectors include viruses such as bacteriophages, baculoviruses, retroviruses, DNA viruses, liposomes and other recombination vectors. The vectors can also contain elements for use in either procaryotic or eucaryotic host systems. One of ordinary skill in the art will know which host systems are compatible with a particular vector.

The vectors can be introduced into the cells by stable or transient transfection, lipofection, electroporation and infection with recombinant viral vectors.

Additional features can be added to the vector to ensure its safety and/or enhance its therapeutic efficacy. Such features include, for example, markers that can be used to negatively select against cells infected with recombinant viruses. An example of such a negative selection marker is the TK gene which confers sensitivity to the antiviral gancyclovir. Features that limit expression to particular cell types can also be included. Such features include, for example, promoter and regulatory elements that are specific for the desired cell type.

Retroviral vectors are another example of vectors useful for the *in vivo* introduction of a desired nucleic acid because they offer advantages such as lateral infection and targeting specificity. Lateral infection is the process by which a

single infected cell produces many progeny virions that infect neighboring cells. The result is that a large area becomes rapidly infected.

A vector to be used in the methods of the invention may be selected depending on the desired cell type to be targeted. For example, if breast cancer is to be treated, then a vector specific for epithelial cell may be used. Similarly, if cells of the hematopoietic system are to be treated, then a viral vector that is specific for blood cells is preferred.

Utility

The antisense oligonucleotides of the present invention may be used for a variety of purposes. They may be used to inhibit the expression of the thioredoxin gene in a mammalian cell, resulting in the inhibition of growth of that cell. They may be used to inhibit the expression of the thioredoxin reductase gene in a mammalian cell, resulting in the inhibition of growth of that cell. The oligonucleotides may be used as hybridization probes to detect the presence of the thioredoxin mRNA or the thioredoxin reductase mRNA in mammalian cells. When so used the oligonucleotides may be labeled with a suitable detectable group (such as a radioisotope, a ligand, another member of a specific binding pair, for example, biotin). Finally, the oligonucleotides may be used as molecular weight markers.

In order to further illustrate the present invention and advantages thereof, the following specific examples are given but are not meant to limit the scope of the claims in any way.

EXAMPLES

In the examples below, all temperatures are in degrees Celsius (unless otherwise indicated) and all percentages are weight percentages (also unless otherwise indicated).

In the examples below, the following abbreviations have the following meanings. If an abbreviation is not defined, it has its generally accepted meaning:

μM	=	micromolar
mM	=	millimolar
M	=	molar
ml	=	milliliter
μl	=	microliter
mg	=	milligram
μg	=	microgram
PAGE	=	polyacrylamide gel electrophoresis
rpm	=	revolutions per minute
ΔG	=	free energy, a measurement of oligonucleotide duplex stability
kcal	=	kilocalories
FBS	=	fetal bovine serum
DTT	=	dithiothrietol
SDS	=	sodium dodecyl sulfate
PBS	=	phosphate buffered saline
PMSF	=	phenylmethylsulfonyl fluoride

General Methods in Molecular Biology:

Standard molecular biology techniques known in the art and not specifically described were generally followed as in Sambrook et al.[24]; Ausubel et al.[25]; and Perbal[26].

Oligonucleotides

The antisense oligonucleotides were selected from the sequence complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA such that the sequence exhibits the least likelihood of showing duplex formation, hairpin formation, and homooligomers/sequence repeats but has a high potential to bind to the thioredoxin mRNA sequence or the thioredoxin reductase mRNA sequence, respectively. In addition, a false priming to other frequently occurring or repetitive sequences in human and mouse was eliminated. These properties were determined using the computer modeling program OLIGO® Primer Analysis Software, Version 5.0 International Biosciences, Inc. Plymouth MN). With regard to the antisense oligonucleotides directed to thioredoxin, 5 oligonucleotides (2601-2605) were selected to target the 5' untranslated region, 2 oligonucleotides (2606-2607) targeted around the translation initiation site, 12 oligonucleotides (2608-2619) targeted the coding region, while 7 oligonucleotides (2620-2626) hybridized to the 3' untranslated region. A total of 66 different antisense oligonucleotides were designed and then ordered from either Dalton Chemical Laboratories, Inc. (North York, Canada) or TriLink Biotechnologies, Inc. (San Diego, CA.)

Cell Lines

Human normal embryonic lung cell line WI-38 and ten different human cancer cell lines including fibrosarcoma (HT-1080), lung carcinoma (A549), ovary adenocarcinoma (SK-OV-3), hepatocellular carcinoma (Hep G2), melanoma (C8161), breast adenocarcinoma (MDA-MB-231), metastatic pancreatic adenocarcinoma (AsPC-1), colon adenocarcinoma (HT-29), cervical carcinoma (HeLa S3), human melanoma cell line A2058, human pancreatic cancer SU.86.86 were obtained from American Type Culture Collection (ATCC). The cell lines were maintained in α-MEM medium (Gibco BRL, Gaithersburg, MD) supplemented with 10% fetal bovine serum (FBS).

Example 1 Overexpression of thioredoxin in human cancer cell lines

Aliquots of cell suspension from different cell lines were added to tissue culture dishes and grown to subconfluency (70-80%). The level of thioredoxin mRNA or protein was determined by Northern or Western blot analysis, respectively.

Northern blot analysis was performed as previously described (Hurta and Wright[23]) with minor modifications. Briefly, total cellular RNA was prepared from cells using TRIzol reagent (Gibco BRL, Gaithersburg MD) at indicated times. RNA (10-20 μg) was fractionated on 1.5% formaldehyde gels and transferred to nylon membranes. The blots were hybridized with ^{32}P-labeled 300 bp PCR fragments synthesized using forward primer [SEQ ID NO:69] (5'-CAG ATC GAG AGC AAG ACT G-3'), reverse primer [SEQ ID NO:70] (5'-TTC ATT AAT GGT GGC TTC AA-3') and human liver 5'-stretch plus cDNA library (Clontech, Palo Alto, CA) as the template. The thioredoxin nucleotide sequence

information was obtained from Genbank accession number X77585. Human thioredoxin mRNA was expressed as a 520 bp transcript (Tagaya et al.[28]) and was visualized and quantified using autoradiography or phosphorImager (Molecular Dynamics, Sunnyvale, CA).

Glyceraldehyde-3-phosphate dehydrogenase (GAPDH) mRNA was simultaneously probed for RNA loading controls. Again PCR was used to generate a 308 bp GAPDH DNA probe using forward primer [SEQ ID NO:71] (5'-CGC GGG GCT CTC CAG AAC AT-3') and reverse primer [SEQ ID NO:72] (5'-GCA ATG CCA GCC CCA GCG TC-3') from the same cDNA library as described above.

As clearly indicated in Fig. 1A, thioredoxin mRNA showed significantly higher levels of expression compared to normal cells in all nine different tumor cell lines. The degree of expression, however, varied among different cell lines and exhibited approximately 1.5 to 5.6 fold ranges of over-expression.

Whole cell protein extracts were prepared in 50 - 150 μl of 2X sample loading buffer (100 mM Tris-HCl, pH 6.8, 0.2M DTT, 4% SDS, 20% glycerol, and 0.015% bromophenol blue). Western blot analysis was performed as previously described (Choy et al.[29] and Fan et al.[30]) with some modifications. The protein extracts (10-20 μg) were fractionated on a 15% SDS-PAGE gel, transferred to nitrocellulose membranes and visualized by India ink staining. The expression of the thioredoxin was detected with anti-thioredoxin antibody (0.2-1 μg/ml) (American Diagnostica Inc., Greenwich, CT) followed by horseradish peroxidase-conjugated antigoat IgG (Sigma, St. Louis, MO) at a dilution of 1:8,000. A protein of approximately 12 kDa was visualized by ECL (Amersham, Arlington Heights, IL).

As shown in Fig. 1B, there was a significant correlation between the levels of thioredoxin mRNA and protein, as the protein expression pattern closely followed the extent of variations observed in the mRNA expression pattern. The lower panel of Fig. 1B shows that the total protein loading was consistent across the panel.

Example 2. The inhibition of growth of cancer cell lines by antisense oligonucleotides complementary to thioredoxin

The colony forming ability of cancer cell lines treated with 26 different antisense oligonucleotides was estimated using a method previously described (Choy et al.[29]). Specifically, aliquots of a tumor cell suspension were seeded into tissue culture dishes at a density of approximately $1X10^4$ and incubated overnight at 37°C in α-MEM medium supplemented with 10% FBS. Cells were washed once in 5 ml of PBS and treated with 0.2 μM of the indicated antisense oligonucleotide in the presence of cationic lipid (Lipofectin reagent, final concentration, 5 μg/ml, Gibco-BRL, Gaithersburg, MD) for 4 hours. The antisense oligonucleotides were removed by washing the cells once with PBS and the cells were cultured in growth medium (α-MEM medium supplemented with 10% FBS) for 7 to 10 days at 37°C. Colonies were stained with methylene blue and scored by direct counting as described (Choy et al. [29] and Huang and Wright[31]). Percent inhibition was calculated by comparison with the number of colonies present in cultures grown in the absence of antisense oligonucleotides. All experiments were performed in quadruplicate.

The antisense oligonucleotides exerted inhibitory effects on the colony forming ability of the human tumor cell lines. The percent inhibition of each antisense oligonucleotide is shown in Fig. 3A for human colon cancer cell line HT-

29; Fig. 3B for human breast cancer cell line MDA-MB-231; Fig. 3C for human liver cancer cell line HepG2: Fig. 3D for human melanoma cell line A2058; Fig. 3E for human ovary cancer cell line SK-OV-3; and Fig 3F for human lung cancer cell line A549.

Example 3 Decreased mRNA levels following treatment with antisense oligonucleotides complementary to thioredoxin

Human liver cancer cells (Hep G2) or breast cancer cells (MDA-MB-231) were grown to subconfluency (70-80%) and were treated with 0.2 μM of phosphorothioate antisense oligonucleotides complementary to thioredoxin for 4 hours in the presence of cationic lipid (Lipofectin reagent, final concentration, 5 μg/ml, Gibco-BRL) and Opti-MEM (Gibco-BRL). Cells were washed once with PBS and incubated for 16 hours in α-MEM medium (Gibco-BRL) containing 10% FBS. Total RNA was prepared in TRIzol reagent (Gibco-BRL) and Northern blot analysis was performed as described earlier. Human thioredoxin mRNA levels were quantitated and normalized to GAPDH mRNA levels and illustrated as a percentage of the thioredoxin mRNA level obtained from untreated cells. Fig. 4A and 4B show that the antisense oligonucleotides reduce the thioredoxin mRNA levels to at least 50% of the control cells.

Example 4 Reduction in thioredoxin protein expression in various cell lines after treatment with antisense oligonucleotides complementary to thioredoxin

Various cell lines were grown to subconfluency (70-80%) and were treated with 0.2 μM of phosphorothioate antisense oligonucleotides for 4 hours in the presence of cationic lipid (Lipofectin reagent, final concentration, 5 μg/ml, Gibco-BRL) and Opti-MEM (Gibco-BRL). Cells were washed once with PBS and

incubated for 20 hours in α-MEM medium (Gibco-BRL) containing 10% FBS. The treatments and incubations were then repeated once more before the whole cell protein extracts were prepared in 2X sample loading buffer (100 mM Tris-HCl, pH 6.8, 0.2M DTT, 4% SDS, 20% glycerol, and 0.015% bromophenol blue) and Western blot analysis was performed as previously described (Choy et al.[29] and Fan et al.,[30]) with some modifications. The expression of thioredoxin was detected with anti-thioredoxin antibody (0.2-1 μg/ml) (American Diagnostica Inc., Greenwich, CT) followed by horseradish peroxidase-conjugated antigoat IgG (Sigma, St. Louis, MO) at a dilution of 1:8,000. A protein of approximately 12 kDa was visualized by ECL (Amersham, Arlington Heights, IL).

The cell lines tested were human colon cancer cells HT-29 (Fig. 5A) and MDA-MB-231 human breast cancer cells (Fig. 5B). The level of protein was reduced by treatment with the indicated antisense oligonucleotides.

Three different human tumor cell lines (HT-29, MDA-MB-231 and HepG2 for colon, breast and liver cancer, respectively) were treated with 0.2 μM of oligonucleotide 2601 [SEQ ID NO:1] as indicated above. Figure 5C shows the inhibition of thioredoxin protein expression by the antisense oligonucleotide in each of the cell lines. The lower panel shows that the protein loading was consistent across the panel.

Example 5. Inhibition of human tumor cell growth in mice by intravenous treatment with antisense oligonucleotides complementary to thioredoxin

CD-1 athymic nude mice were purchased from Charles River Laboratories (Montreal Canada). HT-29 human colon cancer cells (typically $3X10^6$ cells in 100 μl of PBS) were subcutaneously injected into the right flank of 6-7 weeks old CD-1

athymic female nude mice. Each experimental group included 5 mice. After the size of tumor reached an approximate volume of 100 mm^3, typically 5 days post tumor cell injection, different antisense oligonucleotides were administered by bolus infusion into the tail vein every other day at 10 mg/kg. Control animals received saline alone for the same period. Treatments typically lasted 10 days thereafter.

Fig. 6A shows the effects of the antisense oligonucleotides on HT-29 tumor growth in CD-1 nude mice. Antitumor activities were estimated by the inhibition of tumor volume, which was measured with a caliper on average of two day intervals over the span of 9 days. Each point in the figure represents mean tumor volume calculated from 5 animals per experimental group. Analysis of covariance was used to compare the regression curves of mice over time within each treatment group. specific hypothesis of equality of slopes, or equality of intercepts when slopes are equal are derived from the analysis. All analysis used the SAS (Statistical Analysis System) version 6.12. When compared to the saline control each antisense oligonucleotide shown in Fig. 6A inhibited the growth of the tumor with a p value of ≤ 0.0001.

At the end of the treatment (usually 24 hours after the last treatment) the animals were sacrificed and tumor weights were measured. Fig. 6B shows the mean weight of the tumors. The antisense oligonucleotides showed significant inhibitory effects on tumor growth. One-way analysis of variance was used to compare the means of groups of treatments. Where the overall group effect was significant, *a priori* multiple comparisons using the least square means was used to find the pairs of treatment groups that were significantly different. When tumor weight was compared each of the antisense oligonucleotides also showed

statistically significant inhibition when compared to the saline control with p values of ≤ 0.0198 (Fig. 6B)

HT-29 human colon cancer cells were subcutaneously injected into the right flank of 6-7 weeks old CD-1 athymic female nude mice. After the size of tumor reached an approximate volume of 100 mm^3, typically 5 days post tumor cell injection, different antisense oligonucleotides were administered by bolus infusion into the tail vein every other day at 10 mg/kg. Control animals received saline alone for the same period. Mice were sacrificed after 8 injections and excised tumor fragments of similar size were immediately collected into RIPA extraction buffer (50 mM Tris-HCl, pH 7.5, 150 mM NaCl, 1% NP-40, 0.5% sodium deoxycholate, 0.1% SDS, 0.02% NaN_3, 1 mM PMSF and 10 μM leupeptin) and rapidly homogenized for protein preparation. To measure the effects of antisense oligonucleotides on thioredoxin protein levels, Western blot analysis was performed as previously described (Choy et al.[29] and Fan et al.[30]) with some modifications. The protein extracts (10-20 μg) were fractionated on a 12% SDS-PAGE gel, transferred to nitrocellulose membranes and visualized by India ink staining. The expression of thioredoxin was detected with anti-thioredoxin antibody (0.2-1 μg/ml) (American Diagnostica Inc., Greewich, CT) followed by horseradish peroxidase-conjugated antigoat IgG (Sigma, St. Louis, MO) at a dilution of 1:8,000. A protein of approximately 50 kDa was visualized by ECL (Amersham, Arlington Heights, IL). Protein loading in each lane was approximately the same. A part of the blot stained with India ink is shown underneath to demonstrate an equal loading in each lane. It is clear from Fig. 6C that the expression of thioredoxin is reduced in tumor tissue obtained from mice treated with antisense oligonucleotides targeting thioredoxin compared to control tumor tissue obtained from mice treated with saline.

Example 6 Overexpression of thioredoxin reductase in human tumor cell lines

Aliquots of cell suspension from different cell lines were added to tissue culture Petri dishes and grown to subconfluency (70-80%). The level of thioredoxin reductase mRNA was determined by Northern blot analysis.

Northern blot analysis was performed as previously described (Hurta and Wright[27]) with minor modifications. Briefly, total cellular RNA was prepared from cells using TRIzol reagent (Gibco-BRL, Gaithersburg MD) at indicated times. RNA (10-20 μg) was fractionated on 1.5% formaldehyde gels and transferred to nylon membranes. The blots were hybridized with ^{32}P-labeled 330 bp PCR fragments synthesized using forward primer [SEQ IDNO:73] (5'-TTG GCT TAG AAA CCG TAG GG-3'), reverse primer [SEQ IDNO:74] (5'-CCA ATG GCC AAA AGT AAC TA-3') and human liver 5'-stretch plus cDNA library (Clontech, Palo Alto, CA) as the template. Human thioredoxin reductase mRNA was expressed as a 3826 nucleotide transcript (Gasdaska et al.[32]) and was visualized and quantified using autoradiography or phosphorImager (Molecular Dynamics, Sunnyvale CA).

Glyceraldehyde-3-phosphate dehydrogenase (GAPDH) mRNA was simultaneously probed for RNA loading controls. Again PCR was used to generate a 308 bp GAPDH DNA probe using forward primer [SEQ ID NO:71] (5'-CGC GGG GCT CTC CAG AAC AT-3') and reverse primer [SEQ ID NO:72] (5'-GCA ATG CCA GCC CCA GCG TC-3') from the same cDNA library as described above.

As clearly indicated in Fig. 7, thioredoxin reductase mRNA in all nine different tumor cell lines showed significantly higher levels of expression compared to the normal cell line.

Example 7. The inhibition of growth of cancer cell lines by antisense oligonucleotides complementary to thioredoxin reductase

The colony forming ability of cancer cell lines treated with 40 different antisense oligonucleotides was estimated using a method previously described (Choy et al.[29]). Specifically, aliquots of a tumor cell suspension were added to tissue culture dishes at a density of approximately $1X10^4$ and incubated overnight at 37°C in α-MEM medium supplemented with 10% FBS. Cells were washed once in 5 ml of PBS and treated with 0.2 μM of the indicated antisense oligonucleotide in the presence of cationic lipid (Lipofectin reagent, final concentration, 5 μg/ml, Gibco-BRL Gaithersburg MD) for 4 hours. The antisense oligonucleotides were removed by washing the cells once with PBS and the cells were cultured in growth medium (α-MEM medium supplemented with 10% FBS) for 7 to 10 days at 37°C. Colonies were stained with methylene blue and scored by direct counting as described (Choy et al.[29] and Huang and Wright[31]). Percent inhibition was calculated by comparison with number of colonies present in cultures grown in the absence of antisense oligonucleotides. All experiments were performed in quadruplicate.

The majority of the antisense oligonucleotides exerted a moderate inhibitory effect on the colony forming ability of the human tumor cell lines. The percent inhibition of each antisense oligonucleotide is shown in Fig. 8A for human breast cancer cell line MDA-MB-231; Fig. 8B for human melanoma cell line A2058; Fig.

8C for human liver cancer cell line HepG2: and Fig. 8D for human pancreatic cancer cell line SU.86.86.

Example 8 Decreased mRNA levels following treatment with antisense oligonucleotides complementary to thioredoxin reductase

Human colon cancer cells (HT-29) or breast cancer cells (MDA-MB-231) were grown to subconfluency (70-80%) and were treated with 0.2 μM of phosphorothioate antisense oligonucleotides complementary to thioredoxin reductase for 4 hours in the presence of cationic lipid (Lipofectin reagent, final concentration, 5 μg/ml, GIBCO BRL) and Opti-MEM (Gibco-BRL). Cells were washed once with PBS and incubated for 16 hours in α-MEM medium (Gibco-BRL) containing 10% FBS. Total RNA was prepared in TRIzol reagent (Gibco-BRL) and Northern blot analysis was performed as described earlier. Human thioredoxin reductase mRNA levels were quantified and normalized to GAPDH mRNA levels and illustrated as a percentage of the thioredoxin reductase mRNA level obtained from untreated cells. Fig. 9A and 9B show that the antisense oligonucleotides reduced the thioredoxin reductase mRNA levels to less than 50% of the control cell levels.

Example 9 Reduction in thioredoxin reductase protein expression in cells after treatment with antisense oligonucleotides

AsPC-1 human pancreatic cancer cells were grown to subconfluency (70-80%) and were treated with 0.2 μM of phosphorothioate antisense oligonucleotides 3014 [SEQ ID NO:40] and 3037 [SEQ ID NO:63] for 4 hours in the presence of cationic lipid (Lipofectin reagent, final concentration, 5 μg/ml, GIBCO BRL) and Opti-MEM (Gibco-BRL). Cells were washed once with PBS and incubated for 20

hours in α-MEM medium (Gibco-BRL) containing 10% FBS. The treatments and incubations were then repeated once more before the whole cell protein extracts were prepared in 2X sample loading buffer (100 mM Tris-HCl, pH 6.8, 0.2M DTT, 4% SDS, 20% glycerol, and 0.015% bromophenol blue) and Western blot analysis was performed as previously described (Choy et al.[29] and Fan et al.[30]) with some modifications. The expression of the thioredoxin reductase was detected with anti-thioredoxin reductase antibody (0.2-1 μg/ml) (Research Genetics, Inc., Huntsville AL) followed by horseradish peroxidase-conjugated antigoat IgG (Sigma, St. Louis, MO) at a dilution of 1:8,000. A protein of approximately 50 kDa was visualized by ECL (Amersham, Arlington Heights, IL). See Fig. 10.

<u>Example 10. Inhibition of tumor cell growth in mice by treatment with antisense oligonucleotides</u>

HT-29 human colon cancer cells (typically $3X10^6$ cells in 100 μl of PBS) were subcutaneously injected into the right flank of 6-7 weeks old CD-1 athymic female nude mice. After the size of tumor reached an approximate volume of 100 mm^3, typically 5 days post tumor cell injection, different antisense oligonucleotides were administered by bolus infusion into the tail vein every other day at 10 mg/kg. Control animals received saline alone for the same period. Treatments typically lasted 10 days thereafter.

Fig. 11A shows the effects of the antisense oligonucleotides complementary to thioredoxin reductase on HT-29 tumor growth in CD-1 nude mice. Antitumor activities were estimated by the inhibition of tumor volume, which was measured with a caliper on average at two day intervals over the span of 9 days. Each point in the figure represents mean tumor volume calculated from 5 animals per

experimental group. At the end of the treatment (usually 24 hours after the last treatment) the animals were sacrificed and tumor weights were measured. Fig. 11B shows the mean weight of the tumors. The antisense oligonucleotides showed significant inhibitory effects on tumor growth. When compared to the saline control each antisense oligonucleotide shown in Fig. 11A inhibited the growth of the tumor with a p value of ≤ 0.0001. When tumor weight was compared, each of the antisense oligonucleotides also showed statistically significant inhibition when compared to the saline control with p values of ≤ 0.0141. (Fig. 11B)

Example 11. Reduction in thioredoxin reductase protein levels in human tumors in mice by intravenous treatment with antisense oligonucleotides

HT-29 human colon cancer cells (typically $3X10^6$ cells in 100 μl of PBS) were subcutaneously injected into the right flank of 6-7 weeks old CD-1 athymic female nude mice. After the size of tumor reached an approximate volume of 100 mm^3, typically 5 days post tumor cell injection, different antisense oligonucleotides were administered by bolus infusion into the tail vein every other day at 10 mg/kg. Control animals received saline alone for the same period. Mice were sacrificed after 8 injections and excised tumor fragments of similar size were immediately collected into RIPA extraction buffer (50 mM Tris-HCl, pH 7.5, 150 mM NaCl, 1% NP-40, 0.5% sodium deoxycholate, 0.1% SDS, 0.02% NaN_3, 1 mM PMSF and 10 μM leupeptin) and rapidly homogenized for protein preparation. To measure the effects of antisense oligonucleotides on thioredoxin reductase protein levels, Western blot analysis was performed as previously described (Choy et al.[29] and Fan et al.[30]) with some modifications. The protein extracts (10-20 μg) were fractionated on a 12% SDS-PAGE gel, transferred to nitrocellulose membranes and visualized by India ink staining. The expression of thioredoxin reductase was detected with anti-thioredoxin reductase antibody (0.2-1 μg/ml) (Research

Genetics, Inc., Huntsville AL) followed by horseradish peroxidase-conjugated antigoat IgG (Sigma, St. Louis, MO) at a dilution of 1:8,000. A protein of approximately 50 kDa was visualized by ECL (Amersham, Arlington Heights, IL). Protein loading in each lane was approximately the same. See Fig. 12.

Claims:

1. An antisense oligonucleotide comprising from about 17 to about 50 nucleotides wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 2601 - 2626 [SEQ ID NOs:1 - 26] as set forth in Table 1.

2. The antisense oligonucleotide of Claim 1 further comprising one or more phosphorothioate internucleotide linkages

3. The antisense oligonucleotide of Claim 1 further comprising additional nucleotides not complementary to the thioredoxin mRNA.

4. An antisense oligonucleotide comprising from about 17 to about 50 nucleotides wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 3001 - 3040 [SEQ ID NOs:27 - 66] as set forth in Table 2.

5. The antisense oligonucleotide of Claim 4 further comprising one or more phosphorothioate internucleotide linkages

6. The antisense oligonucleotide of Claim 4 further comprising additional nucleotides not complementary to the thioredoxin reductase mRNA.

7. A vector comprising an oligonucleotide sequence comprising from about 3 to 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal.

8. A pharmaceutical composition comprising a pharmaceutically acceptable excipient and an effective amount of the antisense oligonucleotide comprising an oligonucleotide sequence comprising from about 3 to 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal.

9. The pharmaceutical composition of claim 8 wherein the antisense oligonucleotide comprises from about 17 to about 50 nucleotides and comprises a sequence selected from the group consisting of sequences 2601 - 2626 [SEQ ID NOs:1 - 26] as set forth in Table 1.

10. The pharmaceutical composition of claim 8 wherein the antisense oligonucleotide comprises from about 17 to about 50 nucleotides and comprises a sequence selected from the group consisting of sequences 3001 - 3040 [SEQ ID NOs:27 - 66] as set forth in Table 2.

11. A method for inhibiting the growth of a mammalian tumor comprising, administering to a mammal suspected of having the tumor an effective amount of an antisense oligonucleotide comprising from about 3 to about 50 nucleotides complementary to the thioredoxin mRNA of the mammal under conditions such that the growth of the tumor is inhibited.

12. The method according to Claim 11 further comprising the step of administering to the mammal a chemotherapeutic agent.

13. The method according to Claim 11 wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 2601 - 2626 [SEQ ID NOs:1 - 26] as set forth in Table 1.

14. The method according to Claim 11 wherein the oligonucleotide is nuclease resistant.

15. A method for inhibiting the growth of a mammalian tumor comprising, administering to a mammal suspected of having the tumor an effective amount of an antisense oligonucleotide comprising at least about 3 nucleotides to about 50 nucleotides complementary to the thioredoxin reductase gene of the mammal under conditions such that the growth of the tumor is inhibited.

16. The method according to Claim 15 further comprising the step of administering to the mammal a chemotherapeutic agent.

17. The method according to Claim 15 wherein the oligonucleotide is nuclease resistant.

18. The method according to Claim 15 wherein the oligonucleotide comprises a sequence selected from the group consisting of sequences 3001 - 3040 [SEQ ID NOs:27 - 66] as set forth in Table 2.

19. A method for inhibiting the metastasis of a mammalian tumor comprising, administering to a mammal suspected of having a metastatic tumor an effective amount of an antisense oligonucleotide comprising from about 3 nucleotides to about 50 nucleotides complementary to the thioredoxin gene of the mammal under conditions such that the metastasis of the tumor is inhibited.

20. The method according to Claim 19 further comprising the step of administering to the mammal a chemotherapeutic agent.

21. A method for inhibiting the metastasis of a mammalian tumor comprising, administering to a mammal suspected of having a metastatic tumor an effective amount of an antisense oligonucleotide comprising from about 3 nucleotides to about 50 nucleotides complementary to the thioredoxin reductase gene of the mammal under conditions such that the metastasis of the tumor is inhibited.

22. The method according to Claim 21 further comprising the step of administering to the mammal a chemotherapeutic agent.

23. A use of an oligonucleotide comprising from about 3 to about 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal to inhibit tumor cell growth.

24. A use of an oligonucleotide comprising from about 3 to about 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal to inhibit metastases.

25. A use of an oligonucleotide comprising from about 3 to about 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal to prepare a medicament for inhibiting tumor cell growth.

26. A use of an oligonucleotide comprising from about 3 to about 50 nucleotides, which nucleotides are complementary to the thioredoxin mRNA or the thioredoxin reductase mRNA of a mammal to prepare a medicament for inhibiting metastases.

Overexpression of hTrx in human tumor cell lines

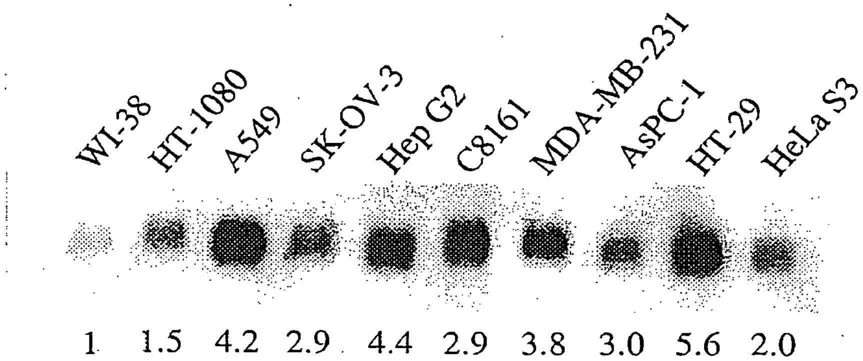


FIG. 1A

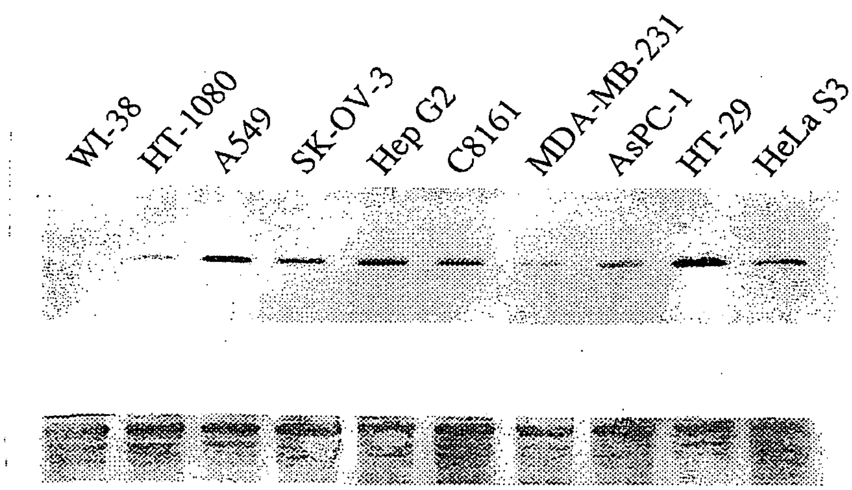


FIG. 1B

GTI2602 GTI2604
GTI2601 GTI2603
agtcttgaagctctgtttggtgctttggatccatttccatcggtccttacagccgctcgt

GTI2606
GTI2605 GTI2607 GTI2608
cagactccagcagccaagatggtgaagcagatcgagagcaagactgctttcaggaagcc
M V K Q I E S K T A F Q E A

GTI2609
GTI2610
ttggacgctgcaggtgataaacttgtagtagttgacttctcagccacgtggtgtgggcct
L D A A G D K L V V V D F S A T W C G P

GTI2612
GTI2611 GTI2613 GTI2614
tgcaaaatgatcaagcctttctttcattccctctctgaaaagtattccaacgtgatattc
C K M I K P F F H S L S E K Y S N V I F

GTI2615 GTI2616 GTI2617
cttgaagtagatgtggatgactgtcaggatgttgcttcagagtgtgaagtcaaatgcatg
L E V D V D D C Q D V A S E C E V K C M

GTI2618
ccaacattccagtttttaagaagggacaaaaggtgggtgaattttctggagccaataag
P T F Q F F K K G Q K V G E F S G A N K

GTI2621
GTI2619 GTI2620
gaaaagcttgaagccaccattaatgaattagtctaatcatgtttctgaaaatataaccag
E K L E A T I N E L V end

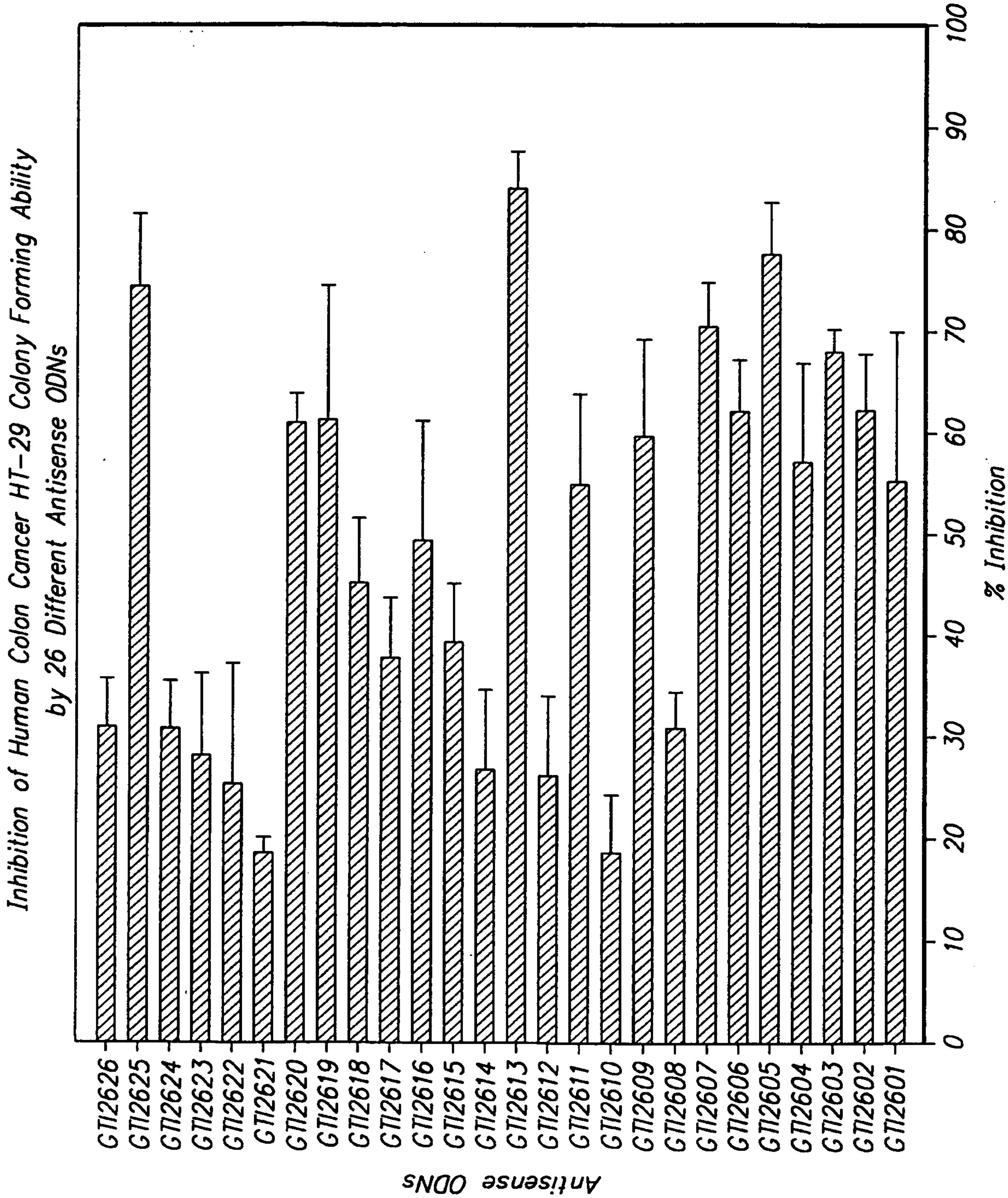
GTI2623
GTI2622
ccattgagctatttaaaacttgtaatttttttaatttacaaaaatataaaatatgaagac

GTI2625
GTI2624 GTI2626
ataaacccagttgccatctgcgtgacaataaaacattaatgctaacacttttttaaaaccg

tctcatgtctgaatagctttcaaaataaatgtgaaatggtc

FIG. 2

FIG. 3A


Inhibition of Human Colon Cancer HT-29 Colony Forming Ability
by 26 Different Antisense ODNs
% Inhibition
0
10
20
30
40
50
60
70
80
90
100
Antisense ODNs
GTI2626
GTI2625
GTI2624
GTI2623
GTI2622
GTI2621
GTI2620
GTI2619
GTI2618
GTI2617
GTI2616
GTI2615
GTI2614
GTI2613
GTI2612
GTI2611
GTI2610
GTI2609
GTI2608
GTI2607
GTI2606
GTI2605
GTI2604
GTI2603
GTI2602
GTI2601

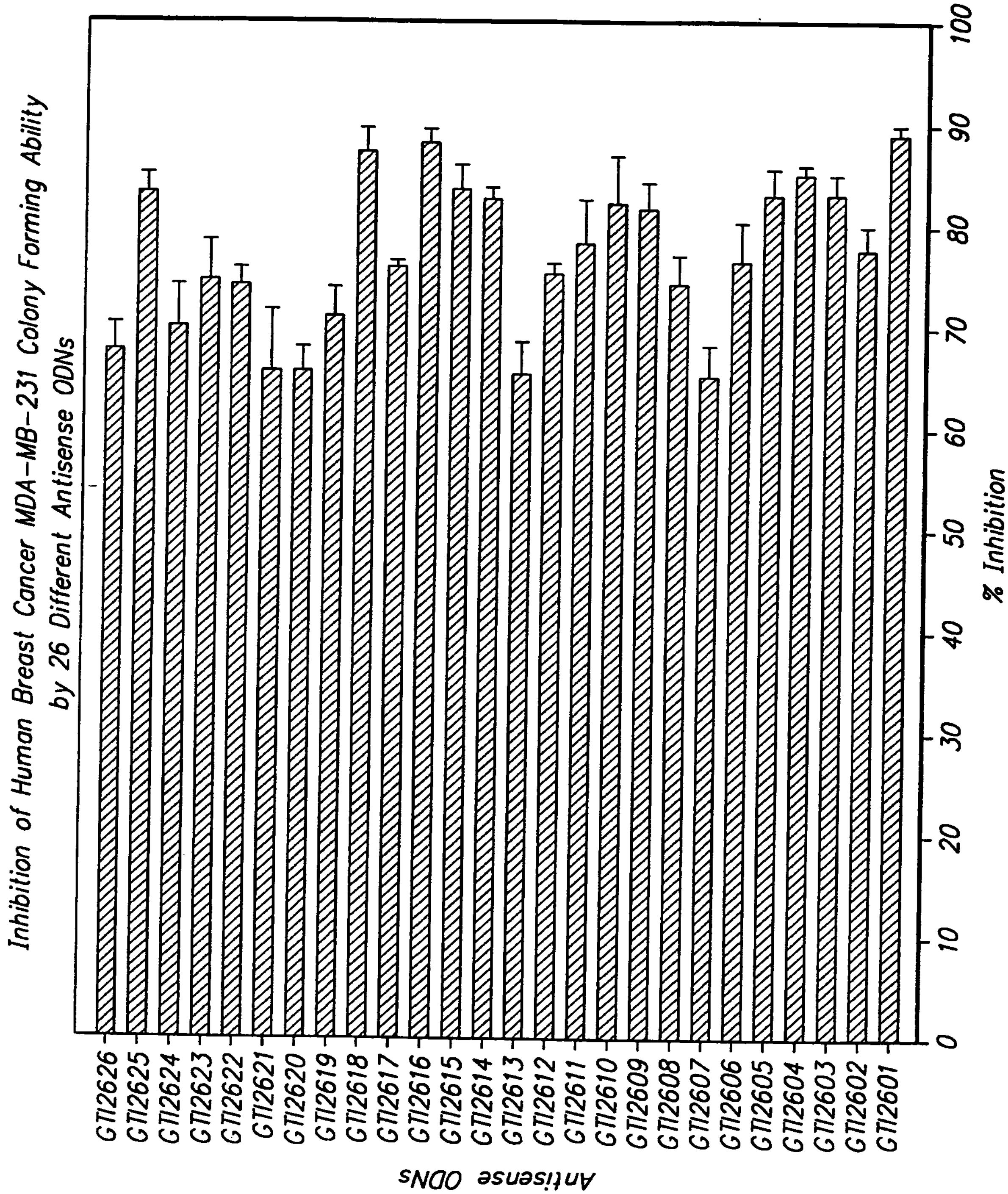
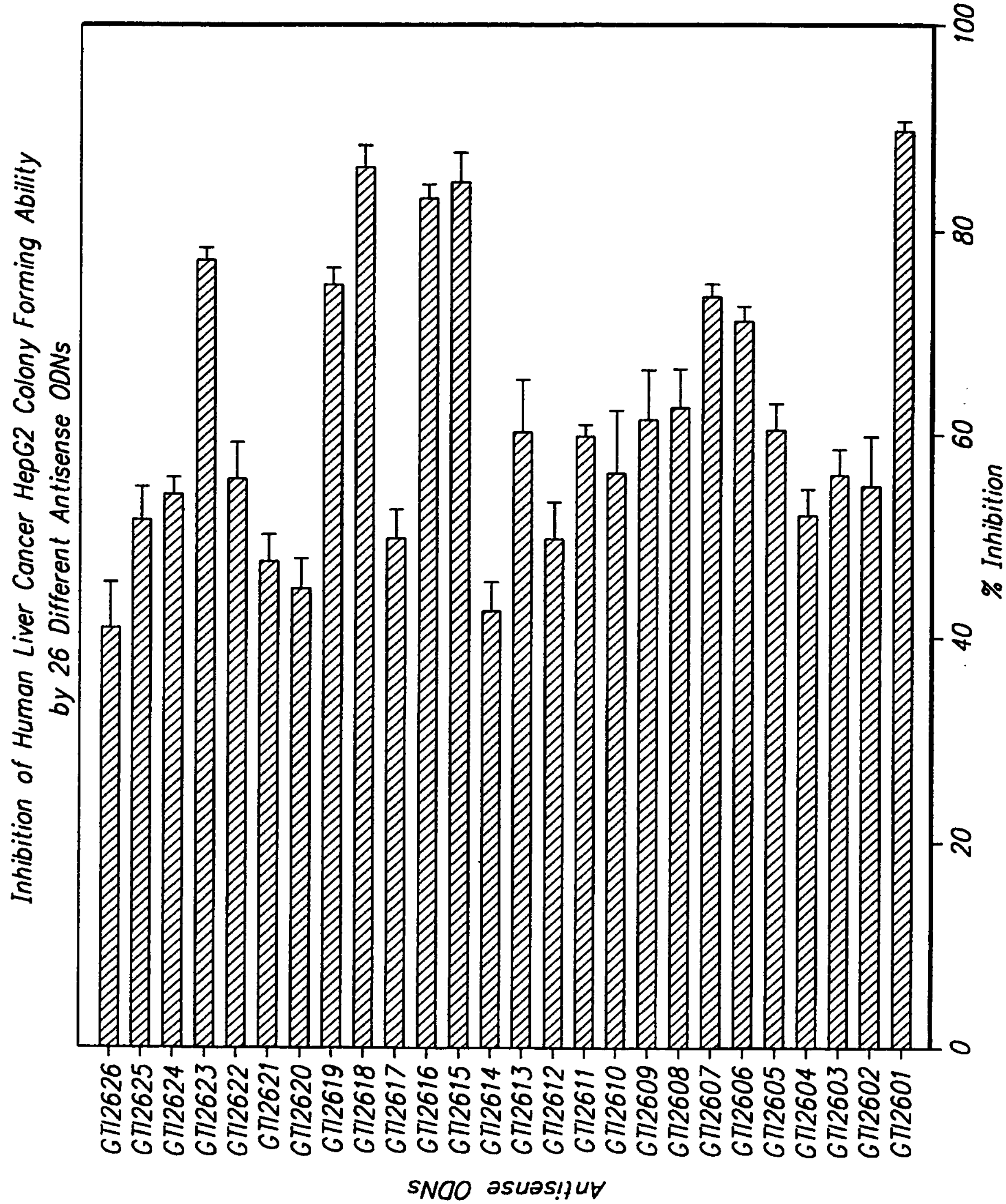

Inhibition of Human Breast Cancer MDA-MB-231 Colony Forming Ability
by 26 Different Antisense ODNs
% Inhibition
0
10
20
30
40
50
60
70
80
90
100
Antisense ODNs
GTI2626
GTI2625
GTI2624
GTI2623
GTI2622
GTI2621
GTI2620
GTI2619
GTI2618
GTI2617
GTI2616
GTI2615
GTI2614
GTI2613
GTI2612
GTI2611
GTI2610
GTI2609
GTI2608
GTI2607
GTI2606
GTI2605
GTI2604
GTI2603
GTI2602
GTI2601

FIG. 3B

FIG. 3C


Inhibition of Human Liver Cancer HepG2 Colony Forming Ability
by 26 Different Antisense ODNs
0
20
40
60
80
100
% Inhibition
GTI2626
GTI2625
GTI2624
GTI2623
GTI2622
GTI2621
GTI2620
GTI2619
GTI2618
GTI2617
GTI2616
GTI2615
GTI2614
GTI2613
GTI2612
GTI2611
GTI2610
GTI2609
GTI2608
GTI2607
GTI2606
GTI2605
GTI2604
GTI2603
GTI2602
GTI2601
Antisense ODNs

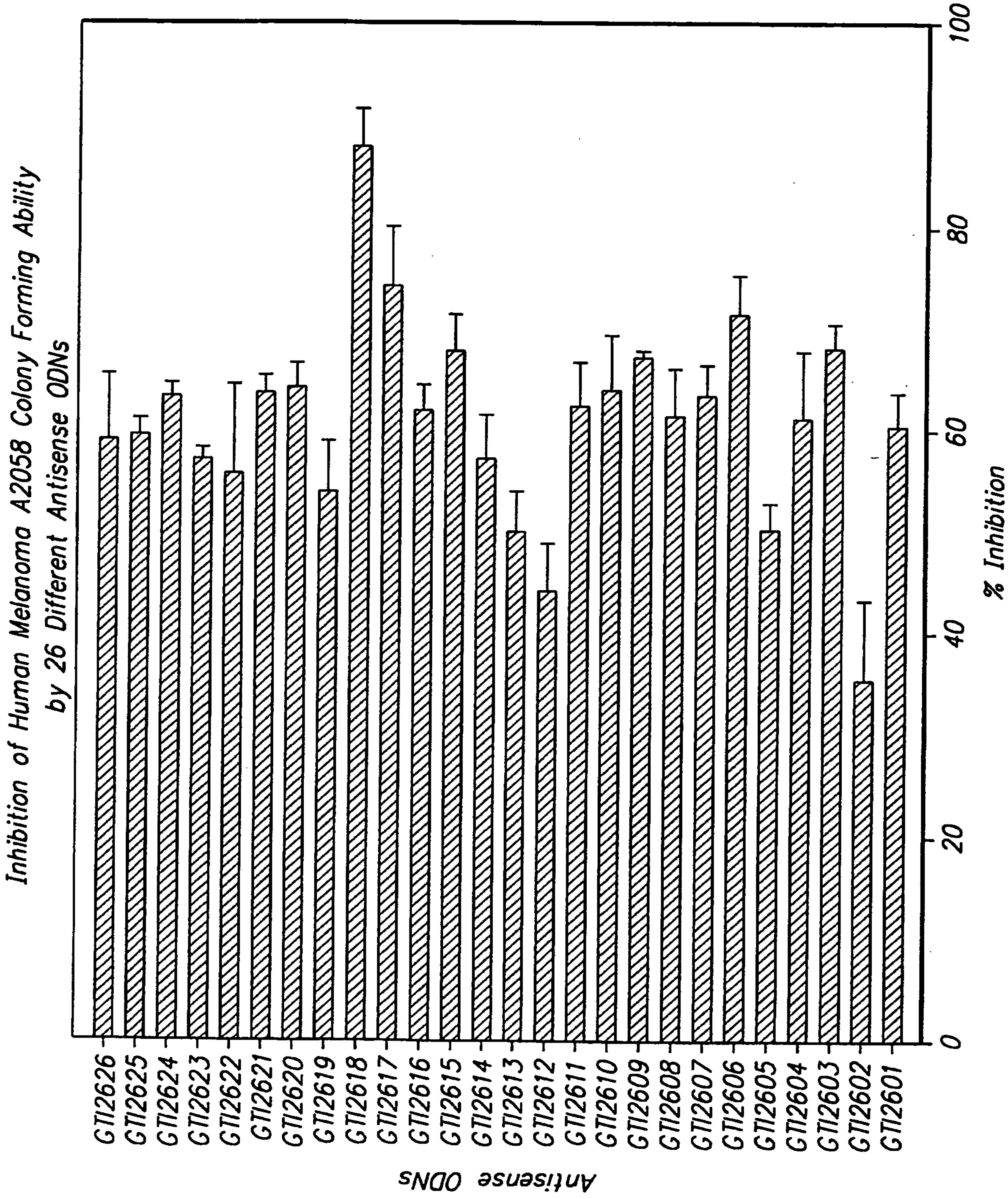

Inhibition of Human Melanoma A2058 Colony Forming Ability
by 26 Different Antisense ODNs
% Inhibition
0
20
40
60
80
100
Antisense ODNs
GTI2626
GTI2625
GTI2624
GTI2623
GTI2622
GTI2621
GTI2620
GTI2619
GTI2618
GTI2617
GTI2616
GTI2615
GTI2614
GTI2613
GTI2612
GTI2611
GTI2610
GTI2609
GTI2608
GTI2607
GTI2606
GTI2605
GTI2604
GTI2603
GTI2602
GTI2601

FIG. 3D

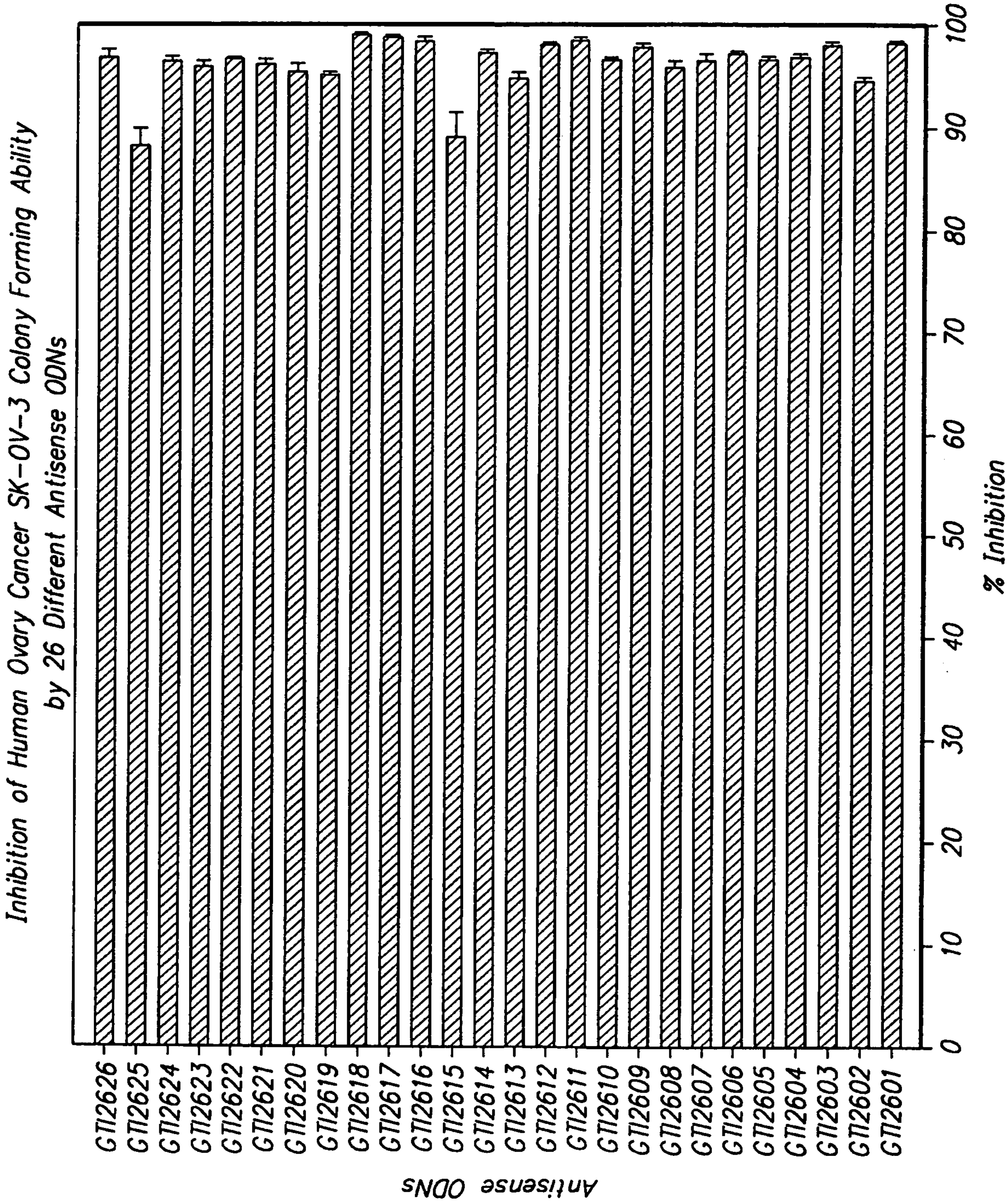
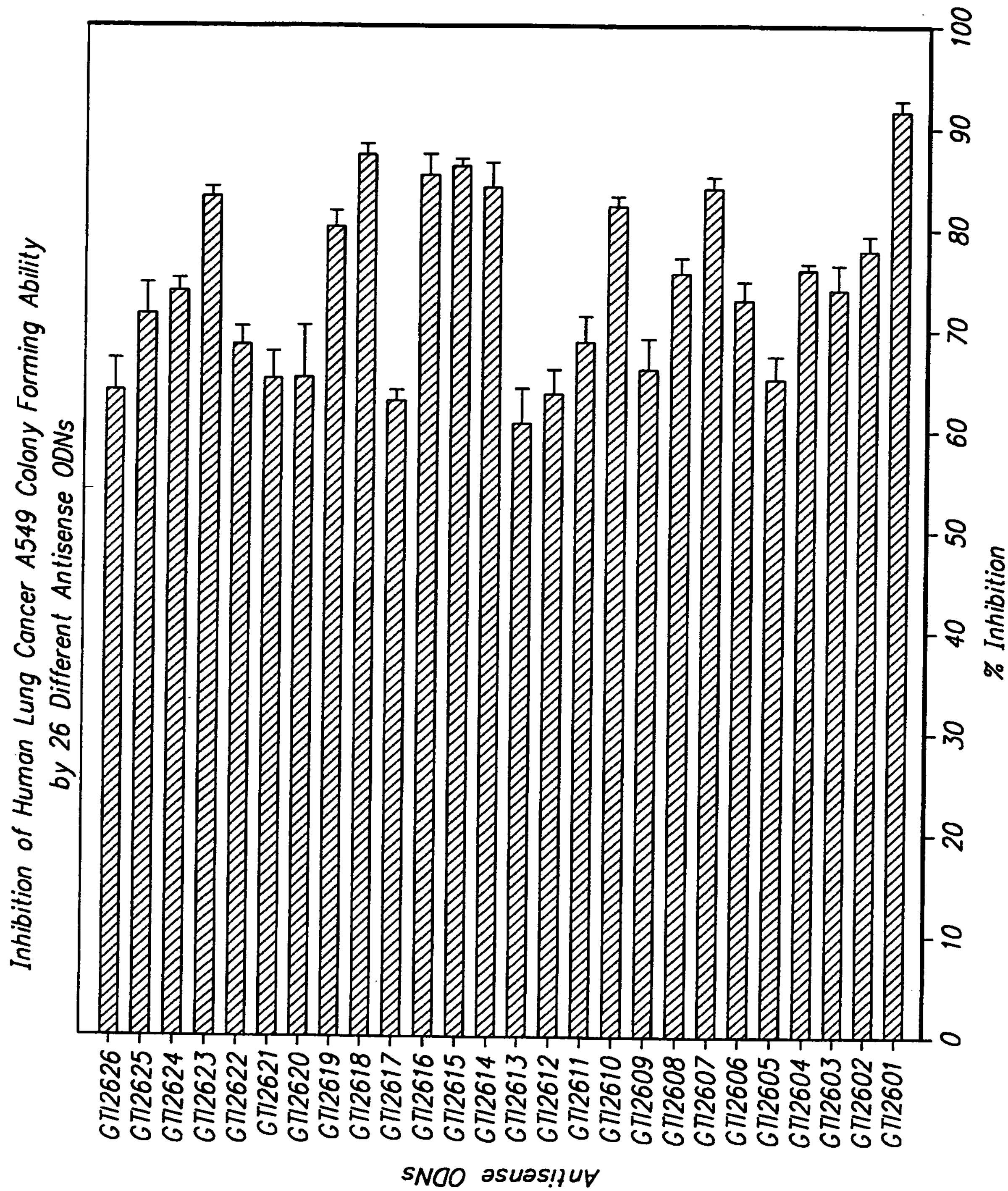

Inhibition of Human Ovary Cancer SK-OV-3 Colony Forming Ability
by 26 Different Antisense ODNs
% Inhibition
0
10
20
30
40
50
60
70
80
90
100
Antisense ODNs
GTI2626
GTI2625
GTI2624
GTI2623
GTI2622
GTI2621
GTI2620
GTI2619
GTI2618
GTI2617
GTI2616
GTI2615
GTI2614
GTI2613
GTI2612
GTI2611
GTI2610
GTI2609
GTI2608
GTI2607
GTI2606
GTI2605
GTI2604
GTI2603
GTI2602
GTI2601

FIG. 3E

FIG. 3F


Inhibition of Human Lung Cancer A549 Colony Forming Ability
by 26 Different Antisense ODNs
% Inhibition
0
10
20
30
40
50
60
70
80
90
100
Antisense ODNs
GTI2626
GTI2625
GTI2624
GTI2623
GTI2622
GTI2621
GTI2620
GTI2619
GTI2618
GTI2617
GTI2616
GTI2615
GTI2614
GTI2613
GTI2612
GTI2611
GTI2610
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GTI2607
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GTI2604
GTI2603
GTI2602
GTI2601

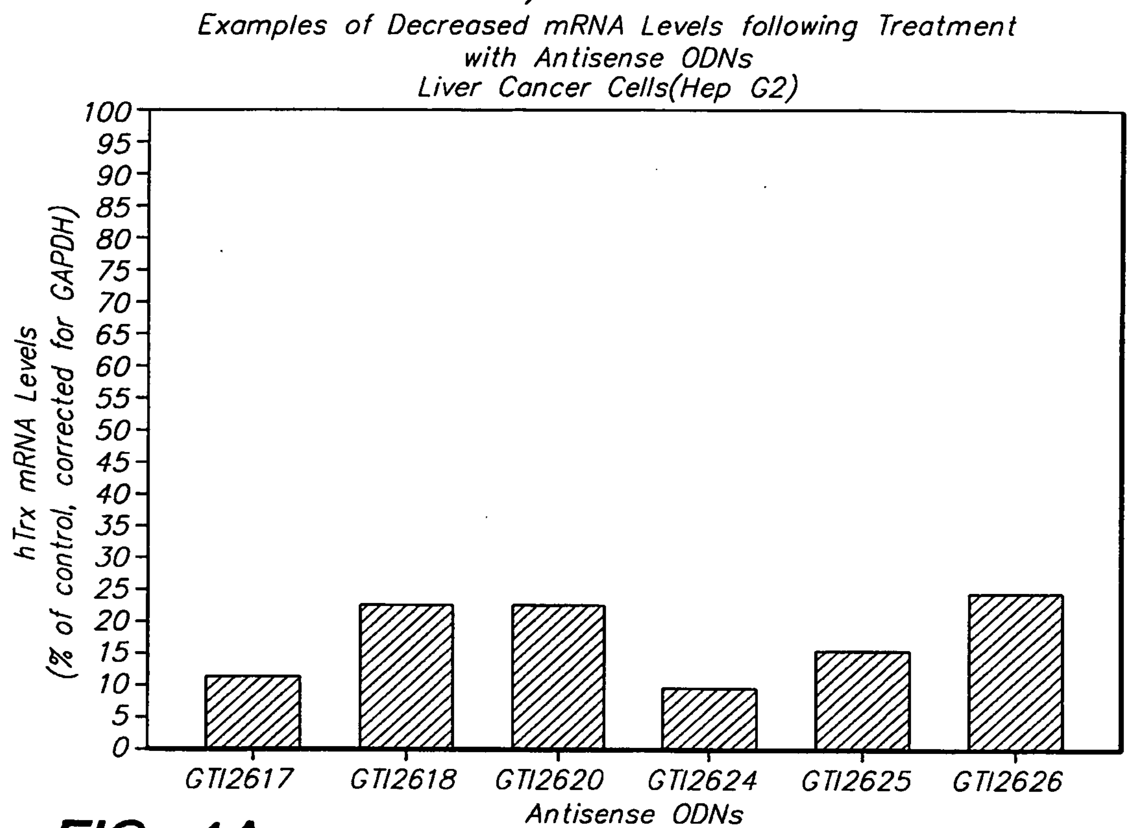

Examples of Decreased mRNA Levels following Treatment
with Antisense ODNs
Liver Cancer Cells(Hep G2)
hTrx mRNA Levels
(% of control, corrected for GAPDH)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
GTI2617
GTI2618
GTI2620
GTI2624
GTI2625
GTI2626
Antisense ODNs

FIG. 4A

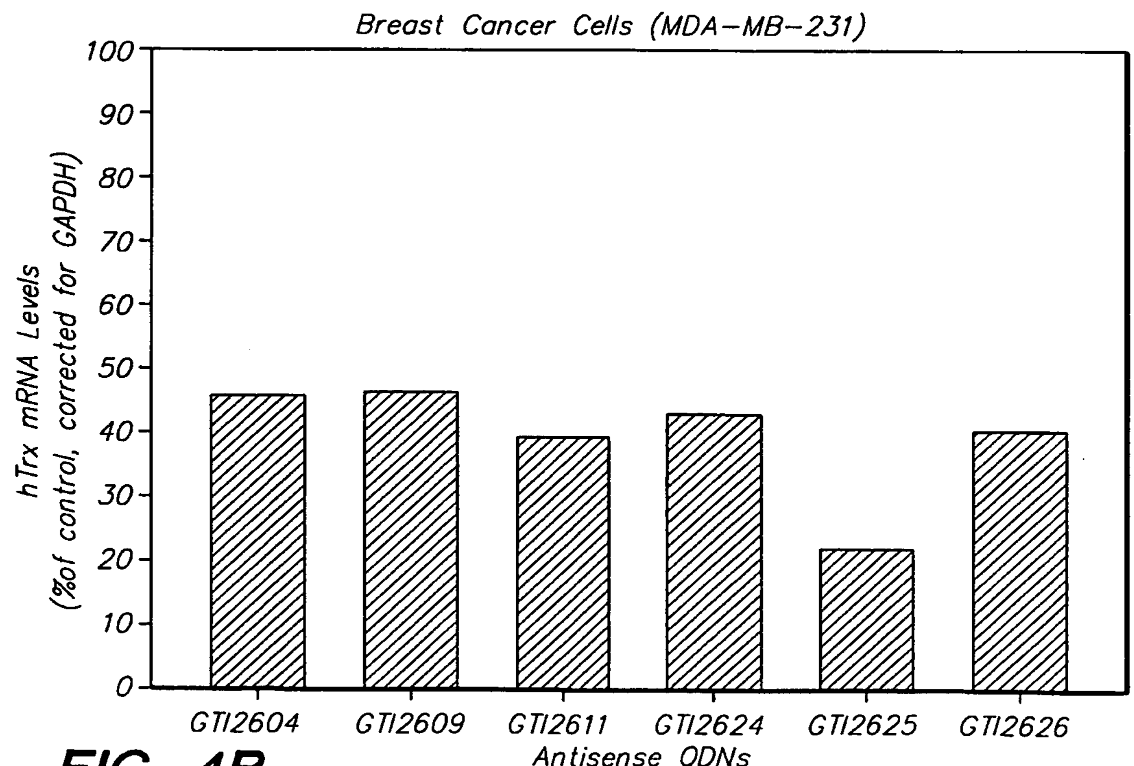

Breast Cancer Cells (MDA-MB-231)
hTrx mRNA Levels
(%of control, corrected for GAPDH)
100
90
80
70
60
50
40
30
20
10
0
GTI2604
GTI2609
GTI2611
GTI2624
GTI2625
GTI2626
Antisense ODNs

FIG. 4B

Reduction in hTrx Protein Expression in Human Colon Cancer Cells by Different Antisense ODNs

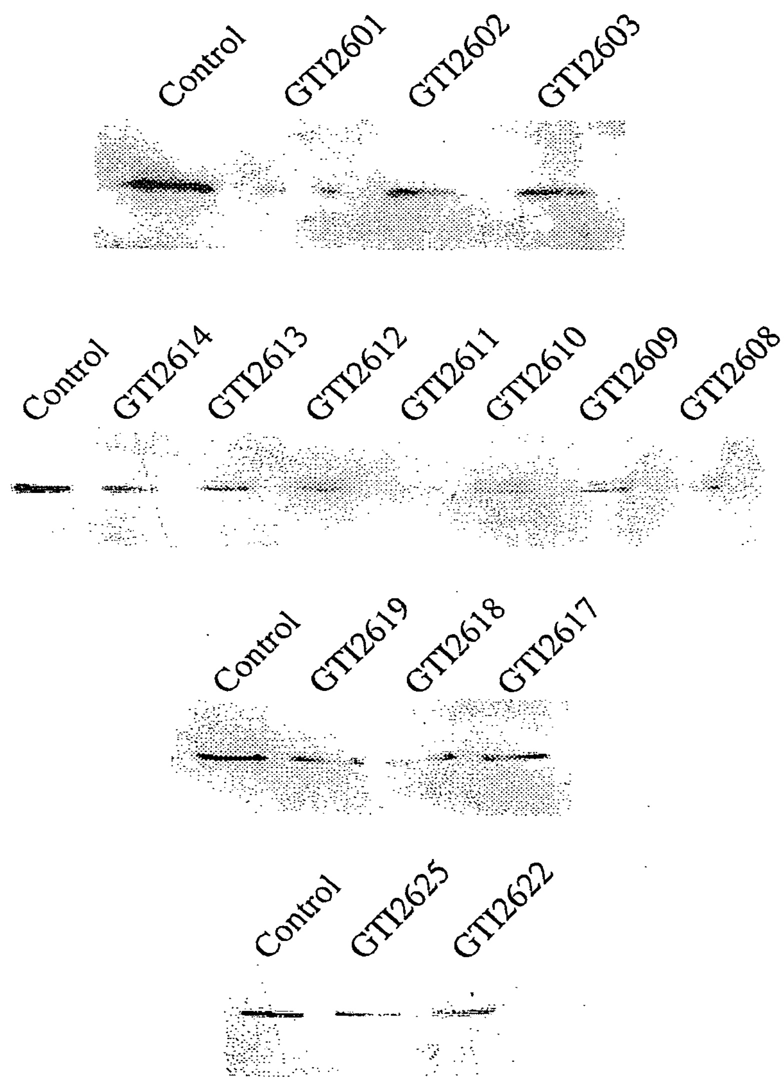


FIG. 5A

Reduction in hTrx Protein Expression in Human Breast Cancer Cells by Different Antisense ODNs

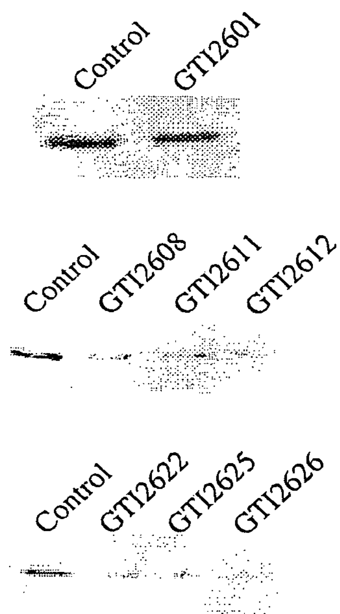


FIG. 5B

GTI2601-mediated Inhibition of hTrx protein Expression in Different Human Cancer Cells

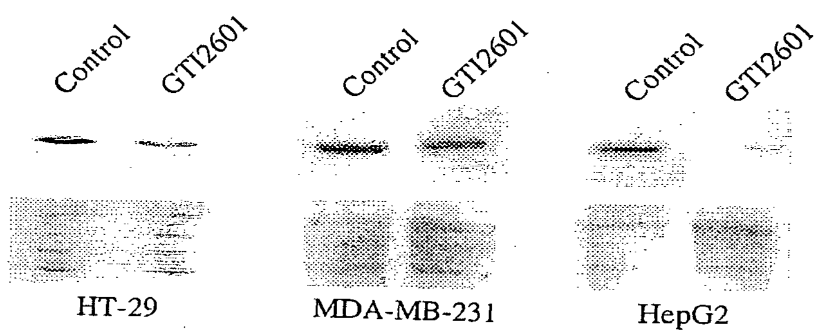


FIG. 5C

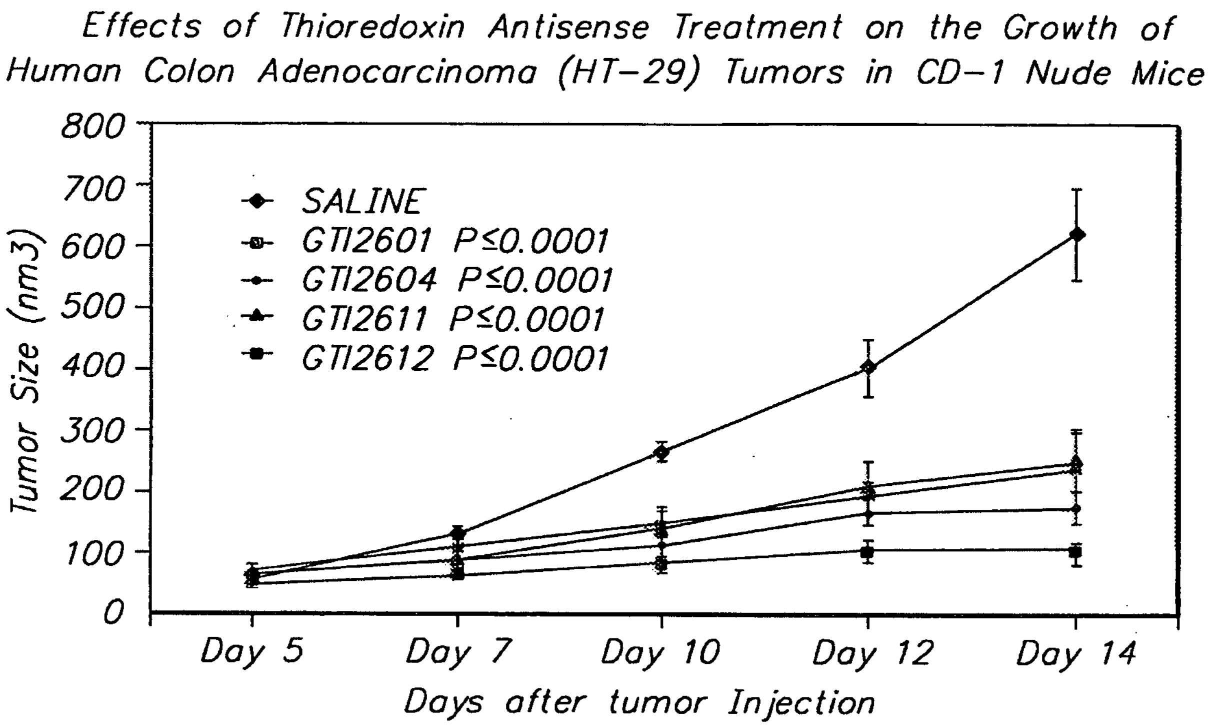

Effects of Thioredoxin Antisense Treatment on the Growth of Human Colon Adenocarcinoma (HT-29) Tumors in CD-1 Nude Mice
SALINE
GTI2601 P≤0.0001
GTI2604 P≤0.0001
GTI2611 P≤0.0001
GTI2612 P≤0.0001
Tumor Size (nm3)
800
700
600
500
400
300
200
100
0
Day 5
Day 7
Day 10
Day 12
Day 14
Days after tumor Injection

FIG. 6A

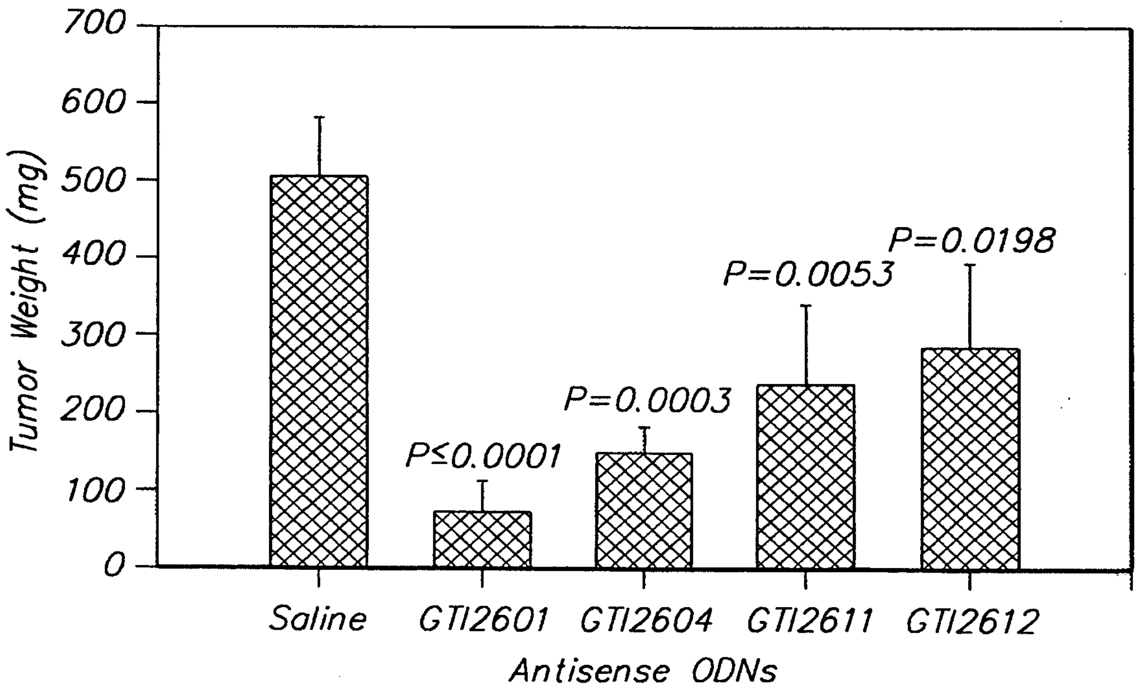

Tumor Weight (mg)
700
600
500
400
300
200
100
0
P≤0.0001
P=0.0003
P=0.0053
P=0.0198
Saline
GTI2601
GTI2604
GTI2611
GTI2612
Antisense ODNs

FIG. 6B

hTrx Protein Levels in Human Colon (HT-29) Tumors

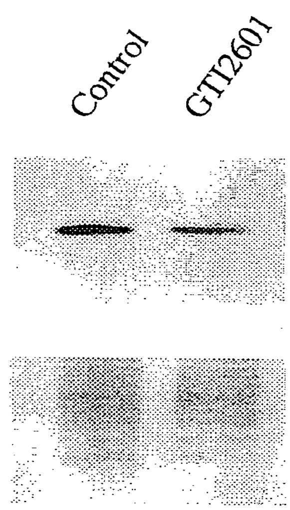


FIG. 6C

Overexpression of hTR in Human Tumor Cell Lines

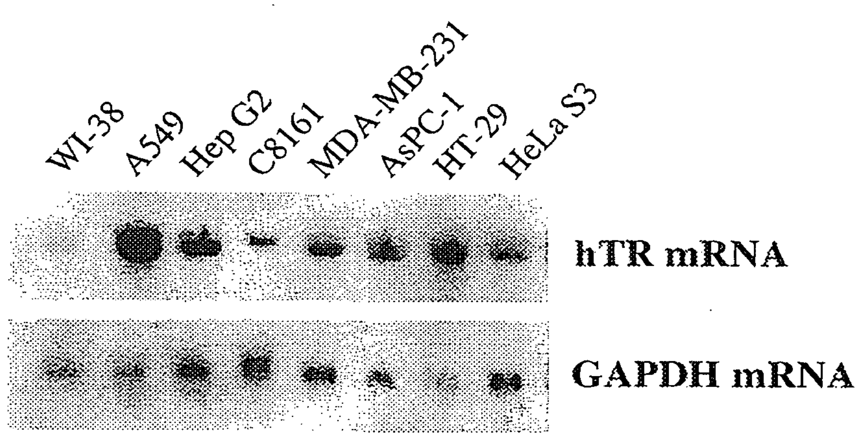


FIG. 7

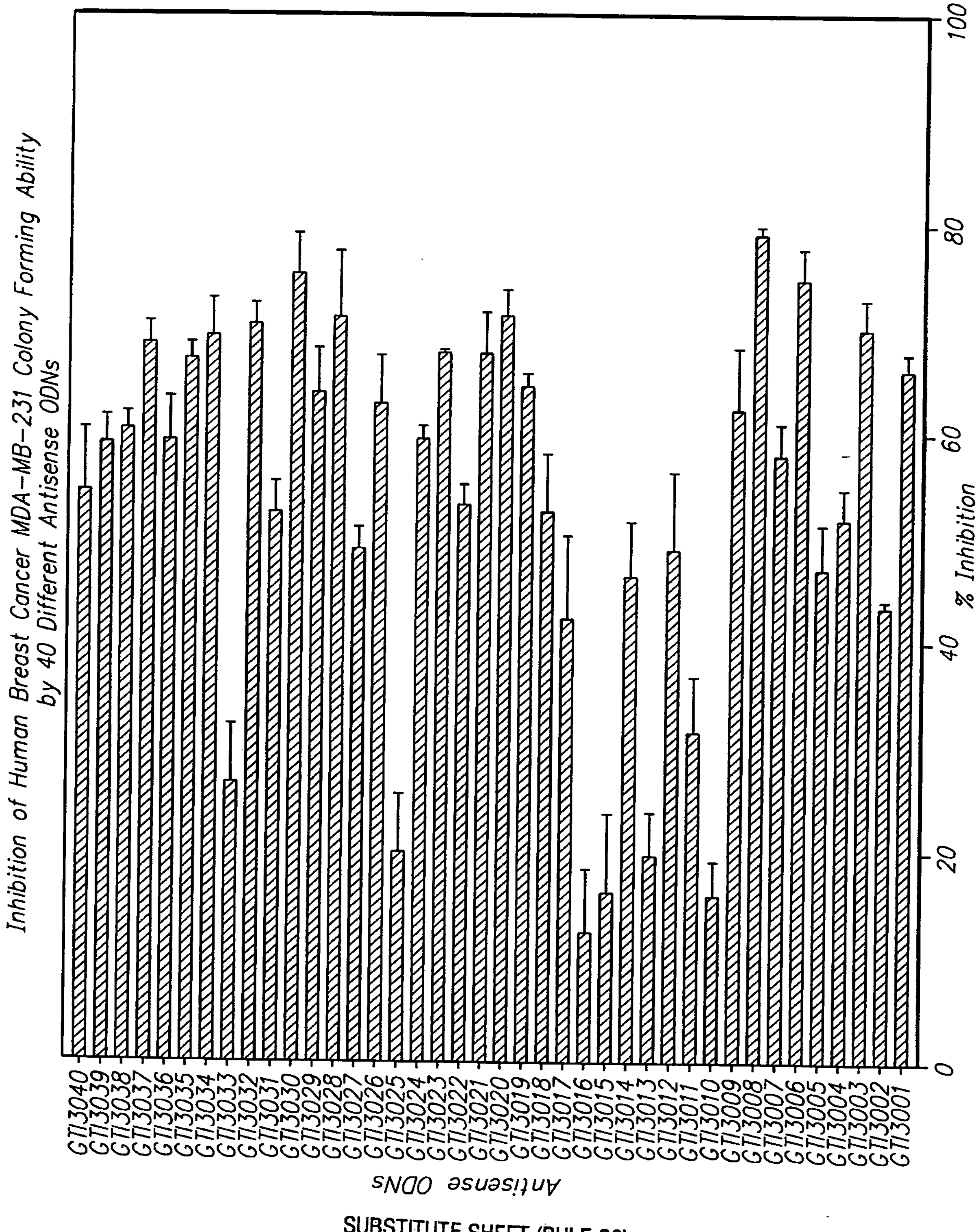
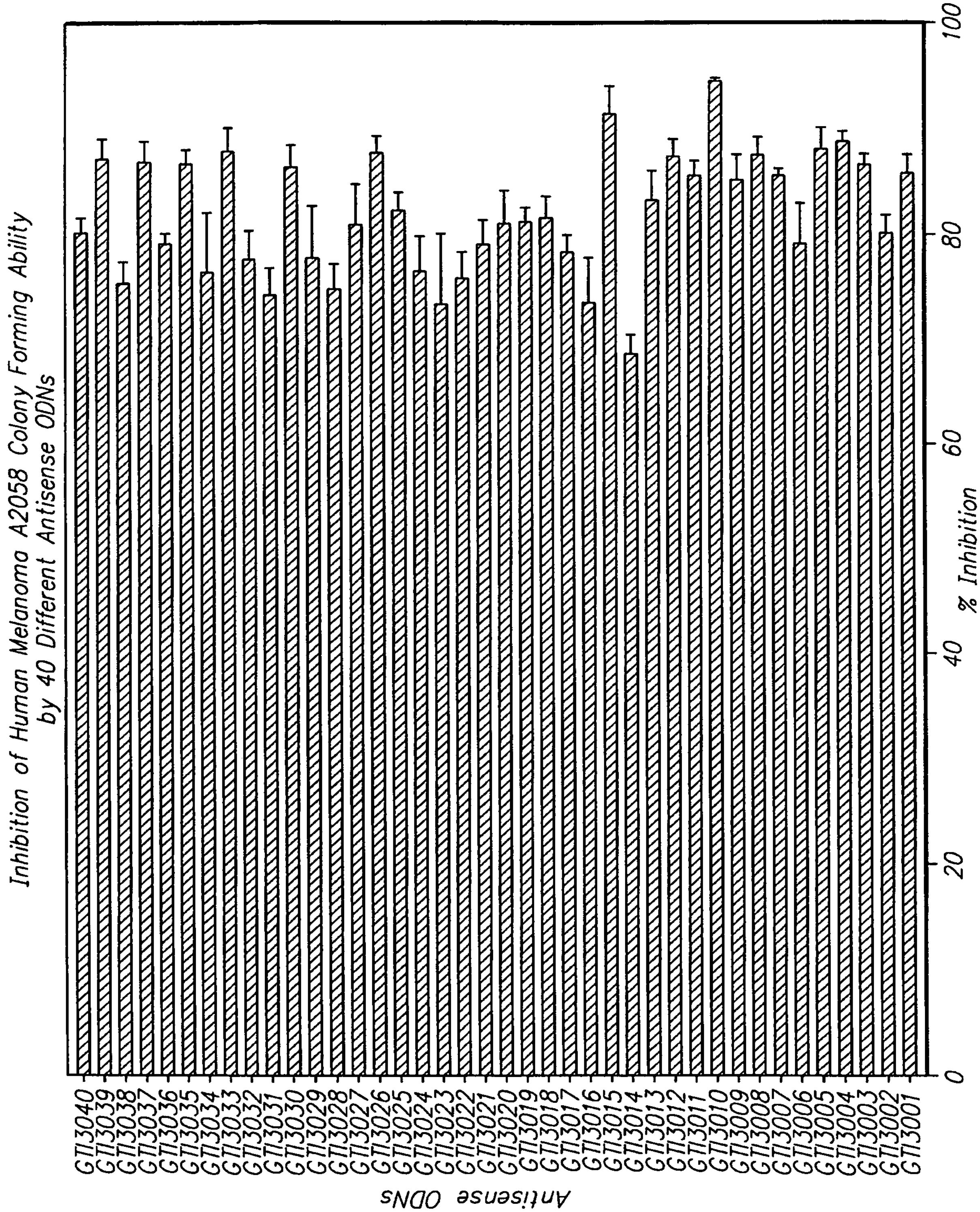

Inhibition of Human Breast Cancer MDA-MB-231 Colony Forming Ability
by 40 Different Antisense ODNs
% Inhibition
0
20
40
60
80
100
Antisense ODNs
GTI3040
GTI3039
GTI3038
GTI3037
GTI3036
GTI3035
GTI3034
GTI3033
GTI3032
GTI3031
GTI3030
GTI3029
GTI3028
GTI3027
GTI3026
GTI3025
GTI3024
GTI3023
GTI3022
GTI3021
GTI3020
GTI3019
GTI3018
GTI3017
GTI3016
GTI3015
GTI3014
GTI3013
GTI3012
GTI3011
GTI3010
GTI3009
GTI3008
GTI3007
GTI3006
GTI3005
GTI3004
GTI3003
GTI3002
GTI3001

FIG. 8A

FIG. 8B


Inhibition of Human Melanoma A2058 Colony Forming Ability
by 40 Different Antisense ODNs
0
20
40
60
80
100
% Inhibition
Antisense ODNs
GTI3040
GTI3039
GTI3038
GTI3037
GTI3036
GTI3035
GTI3034
GTI3033
GTI3032
GTI3031
GTI3030
GTI3029
GTI3028
GTI3027
GTI3026
GTI3025
GTI3024
GTI3023
GTI3022
GTI3021
GTI3020
GTI3019
GTI3018
GTI3017
GTI3016
GTI3015
GTI3014
GTI3013
GTI3012
GTI3011
GTI3010
GTI3009
GTI3008
GTI3007
GTI3006
GTI3005
GTI3004
GTI3003
GTI3002
GTI3001

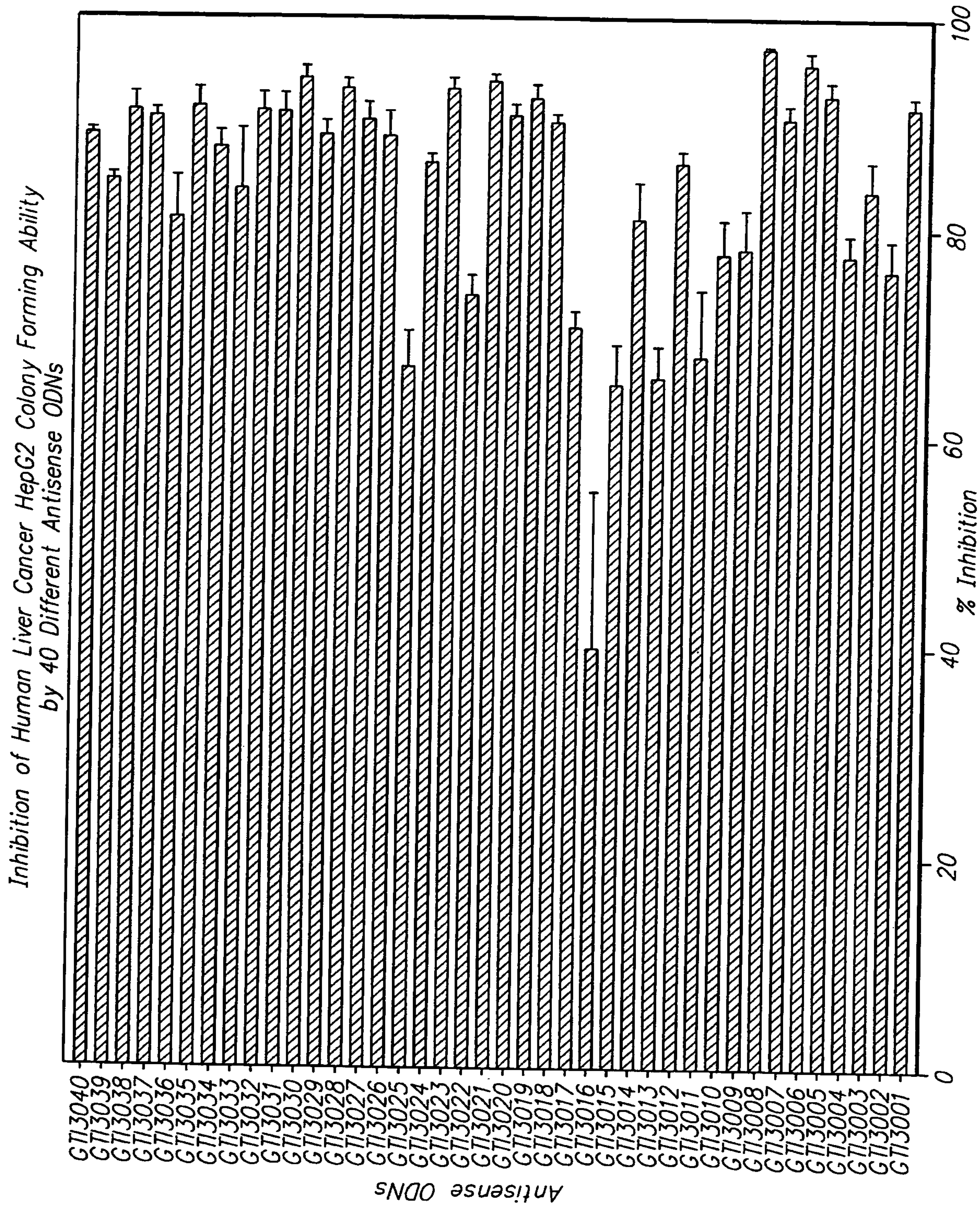

Inhibition of Human Liver Cancer HepG2 Colony Forming Ability
by 40 Different Antisense ODNs
% Inhibition
0
20
40
60
80
100
Antisense ODNs
GTI3040
GTI3039
GTI3038
GTI3037
GTI3036
GTI3035
GTI3034
GTI3033
GTI3032
GTI3031
GTI3030
GTI3029
GTI3028
GTI3027
GTI3026
GTI3025
GTI3024
GTI3023
GTI3022
GTI3021
GTI3020
GTI3019
GTI3018
GTI3017
GTI3016
GTI3015
GTI3014
GTI3013
GTI3012
GTI3011
GTI3010
GTI3009
GTI3008
GTI3007
GTI3006
GTI3005
GTI3004
GTI3003
GTI3002
GTI3001

FIG. 8C

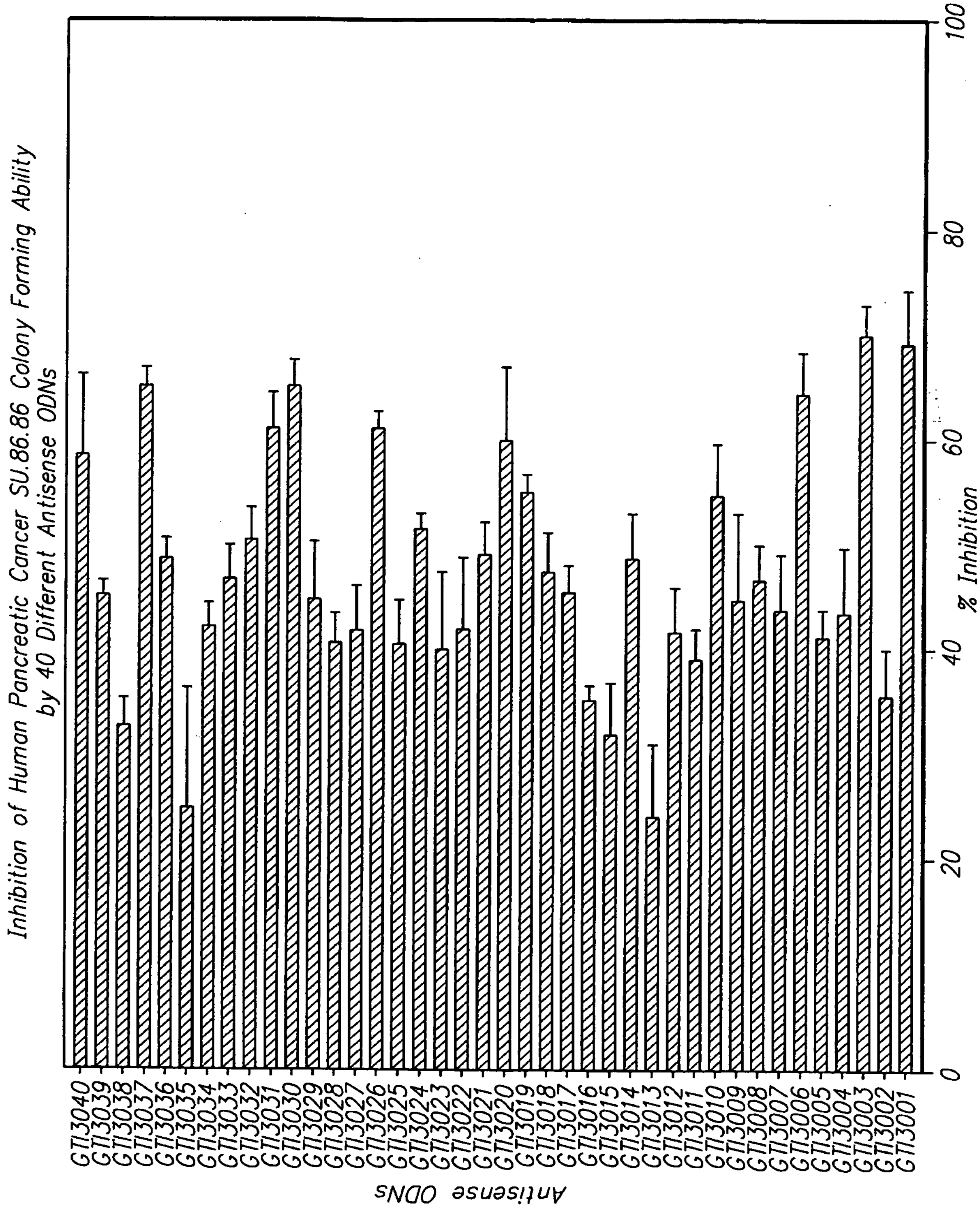

Inhibition of Human Pancreatic Cancer SU.86.86 Colony Forming Ability by 40 Different Antisense ODNs
% Inhibition
0
20
40
60
80
100
Antisense ODNs
GTI3040
GTI3039
GTI3038
GTI3037
GTI3036
GTI3035
GTI3034
GTI3033
GTI3032
GTI3031
GTI3030
GTI3029
GTI3028
GTI3027
GTI3026
GTI3025
GTI3024
GTI3023
GTI3022
GTI3021
GTI3020
GTI3019
GTI3018
GTI3017
GTI3016
GTI3015
GTI3014
GTI3013
GTI3012
GTI3011
GTI3010
GTI3009
GTI3008
GTI3007
GTI3006
GTI3005
GTI3004
GTI3003
GTI3002
GTI3001

FIG. 8D

Examples of Decreased mRNA Levels following Treatment with Antisense ODNs

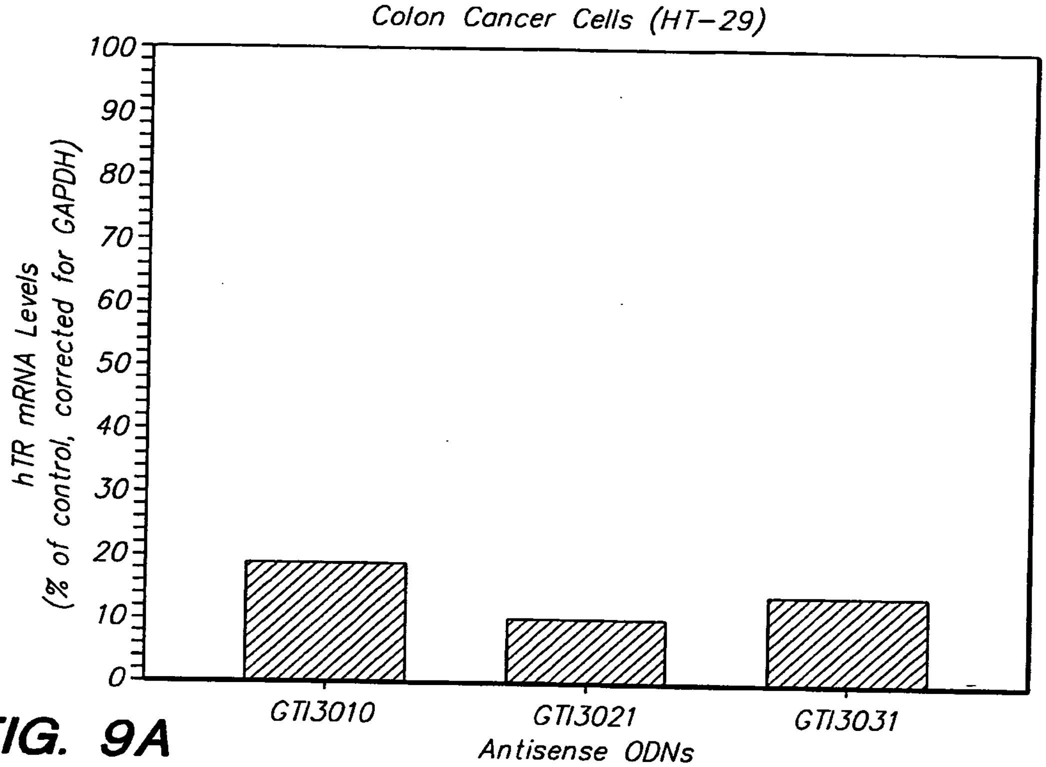


FIG. 9A

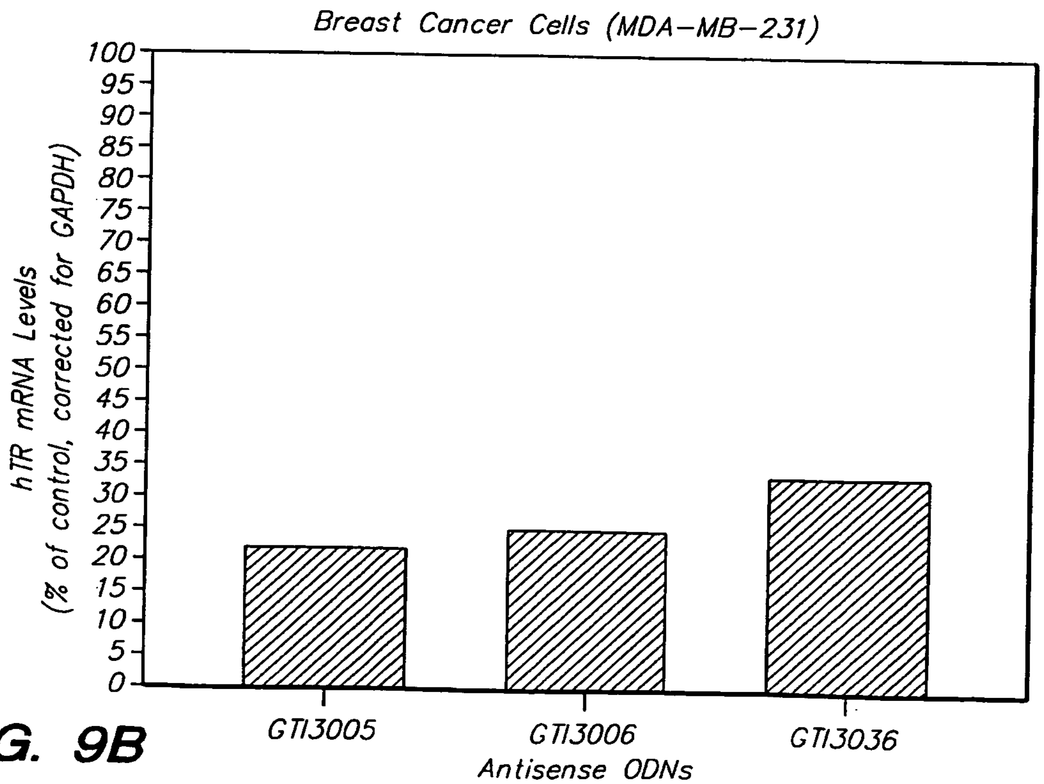


FIG. 9B

Reduction in hTR Protein Expression in Human Pancreatic Cancer Cells by Different Antisense ODNs

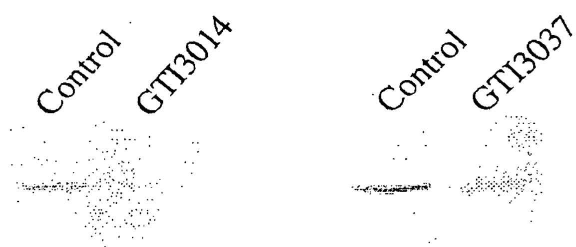


FIG. 10

Effects Thioredoxin Reductase Antisense Treatment on the Growth of Human Colon Adenocarcinoma (HT-29) Tumors in CD-1 Nude Mice

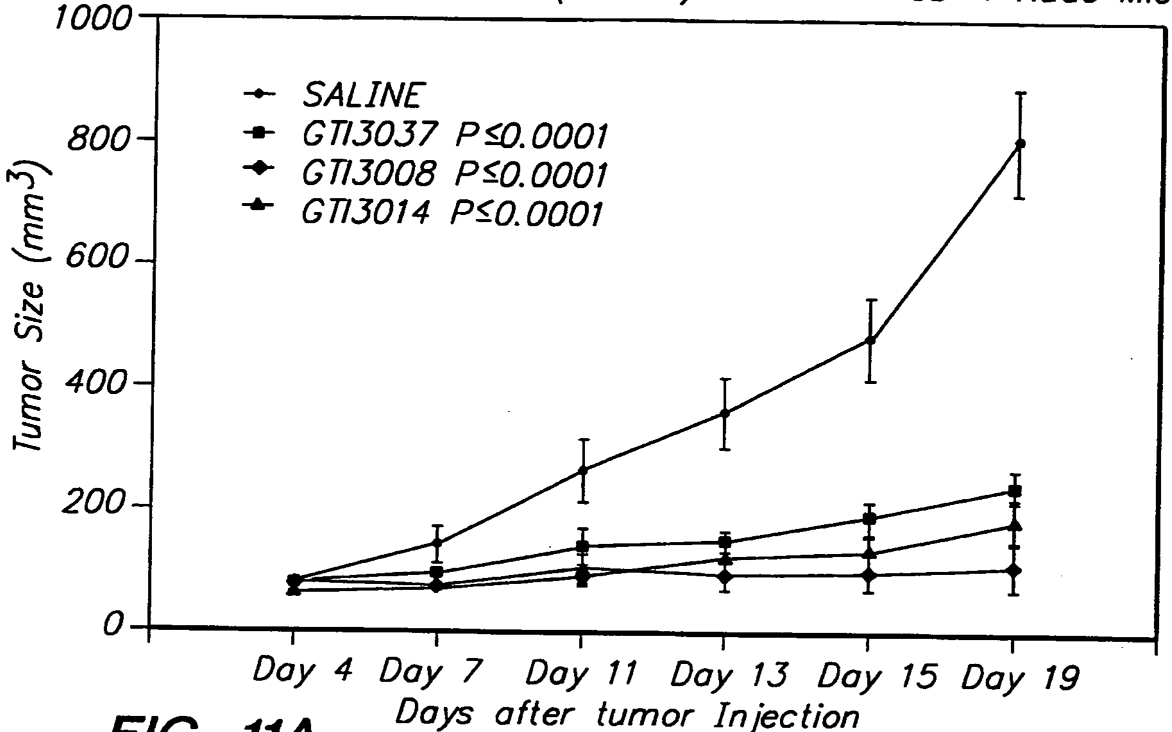


FIG. 11A

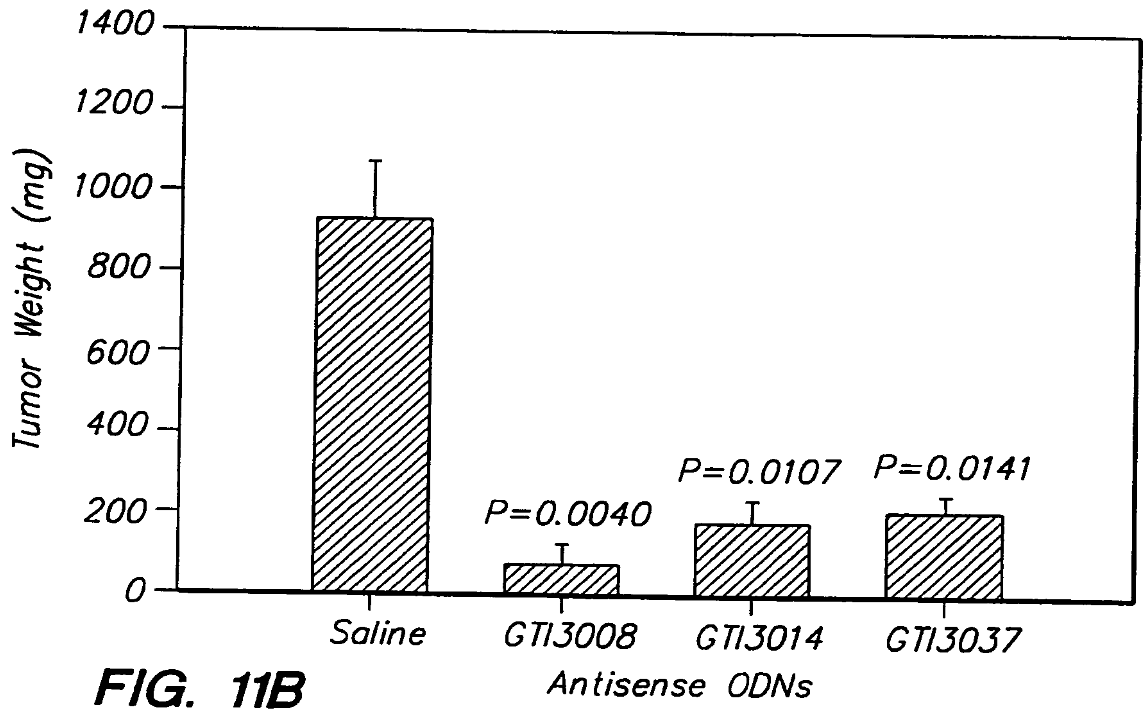


FIG. 11B

hTR Protein Levels in Human Colon Cancer HT-29 Tumors

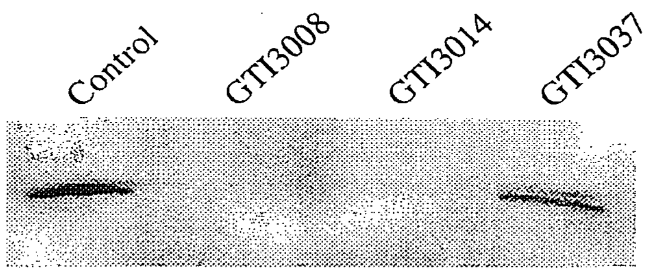


FIG. 12

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 99/00077

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12N15/11 C07H21/04 A61K31/70

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12N A61K C07H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	YOKOMIZO A ET AL: "Cellular levels of thioredoxin associated with drug sensitivity to cisplatin, mitomycin C, doxorubicin, and etoposide." CANCER RESEARCH, (1995 OCT 1) 55 (19) 4293-6., XP002106017 the whole document ---	1-3,7-9, 11-14
A	KUNKEL M W ET AL: "Cell line-directed screening assay for inhibitors of thioredoxin reductase signaling as potential anti- cancer drugs." ANTI-CANCER DRUG DESIGN, (1997 DEC) 12 (8) 659-70., XP002106018 --- -/--	

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 1999	02/07/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Andres, S

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	GALLEGOS A ET AL: "TRANSFECTION WITH HUMAN THIOREDOXIN INCREASES CELL PROLIFERATION AND A DOMINANT-NEGATIVE MUTANT THIOREDOXIN REVERSES THE TRANSFORMED PHENOTYPE OF HUMAN BREAST CANCER CELLS" CANCER RESEARCH, vol. 56, no. 24, 15 December 1996 (1996-12-15), pages 5765-5770, XP002062160 ISSN: 0008-5472 cited in the application the whole document ---	
A	OBLONG, J. ET AL. : "Site-directed mutagenesis of active site cysteines in human thioredoxin produces competitive inhibitors of human thioredoxin reductase and elimination of mitogenic properties of thioredoxin" JOURNAL OF BIOLOGICAL CHEMISTRY., vol. 269, 22 April 1994 (1994-04-22), pages 11714-11720, XP002106019 ISSN: 0021-9258 cited in the application ---	
P,X	SAITOH M ET AL: "Mammalian thioredoxin is a direct inhibitor of apoptosis signal-regulating kinase (ASK) 1" EMBO JOURNAL, (1 MAY 1998) VOL. 17, NO. 9, PP. 2596-2606., XP002106020 page 2601, left-hand column - right-hand column, line 4 figure 7 page 2604, right-hand column, paragraph 3 -----	1,2

INTERNATIONAL SEARCH REPORT	International application No. PCT/CA 99/ 00077

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claims 23 and 24 (as far as in vivo methods are concerned) and claims 11-22 are directed to a method of treatment of the human animal body, the search has been carried out and based on the alleged effects of the compound/composition

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.